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THE RELATION OF PUBLIC SERVICE COMMISSIONS TO THE GAS CONSUMING PUBLIC AND TO THE GAS COMPANIES.*

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I UNDERSTAND that I am asked to try to give to you who are concerned, or who may become concerned, in the administration of governmental bureaus provided to secure the development of the gas industry and the regulation of gas companies, the ideas that the gas industry holds of the obligations of such bureaus to the public and to the gas companies, and of the proper methods of procedure in such regulation and development. While I fully believe that what I have to say expresses the general opinion of the American gas industry, I want you to know that I am not delegated by the industry, or by any gas company, to speak for it in this matter.

The limit of time placed upon me in the invitation to address you, and which I shall but slightly exceed, indicates that I am expected to confine myself to a very general discussion of our subject. I regret this limitation because it cuts from proper consideration many important mooted questions, among others of perhaps only less importance, methods of valuation and of charging, of determining upon what amount of investment the owner is entitled to earn a profit, and of so arranging schedules

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that each customer shall contribute his proper share of the cost of maintaining the gas service.

I ask you to have in mind as I talk to you that I am a layman and speaking the language of a layman to a body of lawyers. I shall tell you the story that I bring as I would tell it to any body of men of a profession other than my own, without an effort to make it other than a plain tale and without thought as to how differently it may appeal to the legal mind than to the lay mind.

I have no list of decisions or citations. The purpose I have in mind is not to enquire what courts and commissions *have* established as to the relations between public and public service corporations—gas companies in particular—but to consider what courts and commissions reasonably may be expected to establish in the intelligent performance of their duties—what they must establish to meet the obligations they have accepted, namely, to secure to the public good gas service at a reasonable price, and to the investor the profit that will be a fair return upon his investment and will hold him, and, as becomes necessary, induce others to the investment.

Also I ask you to remember that we of the public service industries—owners and employees—are American citizens, having the same interest in the establishment and maintenance of correct principles of government, and the wise performance of all governmental functions, as have all other American citizens; and that we necessarily look at the problems we are to discuss to-day not only from the view-point of the operator of a public utility seeking opportunity to perform his function creditably, and usefully, and of the investor in such a utility seeking to protect his investment, but also from the view-point of the citizen seeking to establish and maintain the best ideals and forms of government and in every way possible to strengthen the social fabric.

There are conveniences, comforts and protections of urban life possible to combined effort, impossible to individual effort. Such of these as confer benefits impossible of accurate measurement and of apportionment of cost in proportion to benefits received, or as are of equal benefit to each citizen—each citizen's proper use being of immediate interest to all citizens because of the direct influence on the general health and order, such

conveniences, comforts and protections are ordinarily at the general expense and paid for in taxes. Such are police and fire protection, sewage facilities and the administration of justice. Other such conveniences, comforts and protections, impossible of individual provision, conferring benefits that are susceptible of accurate apportionment of cost, and utilized by the citizen if and when he will, and in quantity as he desires, and as are substantially without the factor of general benefit from individual use, are ordinarily provided at a price per unit of service rendered. Such are the gas supply, the electricity supply and the street car service.

There is no question of the importance of each of these agencies of civilization or of the duty of government to secure their benefits to the citizen. On this point, Mr. Walter L. Fisher, recently Secretary of the Interior, closes his essay, "The American Municipality," with these words: "What must be recognized is that the city cannot escape its primary obligation so to develop and control its public utilities, whether in public or in private hands, that they shall be effective instruments for the service of the individual citizen and the development of the organized community."

The development and control of public utilities being a function of the state, and the state having power to delegate its functions, this function of development and control may be performed directly by the state or by such delegate, whether company, municipality, commission or other, as the state may select or create for the purpose.

Since Mr. Fisher wrote his essay in 1906, the legislatures of the majority of the states of the Union have delegated this duty and authority to so-called Public Utility Commissions. The power of decision in matters of price of gas, quality of gas, character of service, raising of capital, issuance of securities, etc., so far as theretofore a function of gas companies generally, has been taken from them and lodged in state commissions. With this shift in power from company to commission necessarily has occurred a corresponding shift in responsibility.

Such state created commissions are now in existence in about forty states and territories. The group of states having commissions charged with full or with some lesser measure of control of gas companies, and with responsibility for the pro-

tection and extension of the gas industry, now includes all of the larger states and contains about eighty per cent. of the total population of the Union. Therefore, the condition which Mr. Fisher declares to be an unescapable municipal obligation to secure, must now be secured through the action or with the consent of a state public utilities commission in most of the states of the Union.

It is profitless to discuss the necessity to the public good for the formation of state commissions to develop and regulate gas companies, as it is to study the causes of the public agitation resulting in commission legislation. Commissions are a fact, and the gas industry generally will admit that where operated with intelligent good intent they will afford a solution of the difficulties ever existent where a corporation has a monopoly of the supply of a necessity. We of the gas industry do this without abatement of our claim that in the past we have properly ordered our affairs and have been in the best sense public servants. Our past is our convincing witness.

We gas men, by our experiments, by our searching of the laws of nature, by our canvassing, by our insistence and persistence in getting consumers to use appliances that would be useful to them and save them money, have so extended the sale and reduced the cost of gas, while greatly improving the quality, that we have been enabled to reduce the price per unit to 40 per cent. or less of what it was a generation ago. This is truly public service, and to the result there is no parallel in the history of industry. We are no factor in the high cost of living. In the algebraic sum that represents the increase in the cost of living, we are a negative quantity. In no other line of industry will you find such a history; such a record. I say it, seriously, confidently and with pride. And it has come through conscientious work and the adventurous investment of enormous sums of stockholders' money. We do not assert an altruistic motive, but we believe that our accomplishment to the public good justifies our claim that we are in the best sense public servants.

The business of the manufacture and supply of illuminating gas is about one century old. From the beginning it has been an important factor in community life. This importance has enormously increased during the last quarter of a century. To-day, no factor more important enters into the life of the urban popu-

lation—except perhaps such as have to do directly with the health and peace of the community; and on these a well ordered street lighting system has a highly beneficial influence.

In the earlier years of the industry's life the use of gas was almost exclusively for the production of light. "Candle power" was its most important quality. The industry's development has been coincident with that enormous extension of knowledge of physical science which has marked the last century. It has kept pace in growth and development toward scientific perfection with the general industrial movement of the century. And this development has brought gas very largely into fields of usefulness where its heating power is its most valuable characteristic. It has become, decade by decade, more important to the prosperity of communities. Since the beginning of this century, and mainly through the convenience and cheapness of gas as a heating agent, the industry has increased in importance as a social factor in measure greater probably than has any other industry. This largely has come through the introduction of gas for cooking and water heating to city kitchens and particularly to the kitchens of people whose related women folk do the family cooking. A little thought will convince you that the 360,000 gas equipped kitchens now in the city in which I am writing must represent the release of a host of women from a large measure of the drudgery of their lives. But unless you have had definite information on the subject you probably do not realize how great is the saving of time and labor. Careful observation justifies the statement that the use of gas for cooking and water heating saves an average of about one hour a day of the time of one woman or girl cook in each of 360,000 homes. One hour a day release from the duties of fire building, coal carrying, ash removing and the consequent cleaning of vessels, implements and surroundings; and one hour per cook per day is over eighty years of twelve hour days—eighty years of twelve hour days of woman's disagreeable labor saved each day in one city by the use of gas heated domestic appliances! Statesmen and economists must recognize this as certainly a factor of the highest importance, and as marking the continuance and extension of the industry as essential to the maintenance and development of the best condition of urban life. And in this time of stress, with need in war work for every available hour and unit of energy, this eighty years of woman's

hard and disagreeable labor economized per day in one city is an enormously valuable asset to the nation.

With the war the gas industry has become the principal source of some of the most important raw materials of explosives. About 30 per cent. of the hydrocarbon bases of the explosives now being used by us and our allies are coming from gas manufacturing plants. Thus in war the industry contributes one of the necessities of the nation's protection, as at all times it supplies one of the comforts of modern domestic urban life. These two uses for gas with their beneficent influence on women's lives and on the security of the nation, and with the economy of the material resources of the nation which are incident to them, so clearly mark gas service as one of the necessities of modern life that I regard them as proving the claim expressed by Mr. Fisher that its development and control is one of the primary obligations of government. I feel it is not necessary to dwell upon the importance of gas as an illuminant in millions of homes and on thousands of miles of highways, and its wide and growing use as a labor and material economizing source of heat in scores of industries—many of them industries essential to the conduct of modern warfare.

This relation of the gas industry to the public good has come to full recognition in this country only within the last quarter of a century. The importance to the public welfare of insuring its efficiency and prosperity, and these at the lowest possible cost to the user of gas, is now no longer a matter of debate. The realization of this importance to the public welfare has found most recent expression in the formation of state commissions—whose functions we are now considering.

The political history of the gas industry shows that from its earliest days the general effort of governmental bodies has been to secure the establishment and maintenance of the industry —however unwise and ungenerous has sometimes been governmental treatment of gas supplies of apparent prosperity. The gas industry's political history is the story of governmental effort first to establish, next to regulate by unelastic provisions and competition, and finally, through commissions or so-called "sliding scale" agreements, intelligently to develop and regulate the business of gas supply.

The history of this governmental effort must be of interest

to the student of public utilities in their relation to government and to people.

About the beginning of the nineteenth century certain philosophers and experimenters in Great Britain and France were brought by their studies and experiments to believe that it was possible to manufacture and to distribute to the inhabitants of cities a source of light and heat that would be always ready for use, require no storage on the premises of the user, be measured as used, and leave no ashes or other undesirable evidence of its presence and use. Some few men of financial means were among the believers. The realization of this belief, which Napoleon characterized as "Une grande folie," and Walter Scott called the "Dream of a mad man," came with the introduction of illuminating gas to London under a charter granted in 1812 in the name of George III, King of Great Britain.

While a few dreamers had had faith, the public had scoffed. Parliament, when finally brought to realize how great might be the importance to the community of such a service as the dreamers prophesied, was liberal in the terms given to the speculative investors. The charter granted the "Gas Light and Coke Company"—the first gas charter ever granted anywhere—imposed no restrictions except that the extent of the experiment, and therefore of the possible loss, was limited by limiting the amount of capital permitted to be raised. In the fixing of the price and quality and of conditions of supply the Company was left to the exercise of its own judgment and will. Regulation was impracticable from any point of view. Nobody knew, or could know, what it would cost to make gas, what the quality of the gas would be, nor even in what terms of comparison the quality would be expressed. Nor was it known what measure of competition the gas supply would find in candles and whale oil—the illuminants of that time. It was seen that a gas supply as forecast would be highly useful and it was known that it would have to commend itself in price and quality in order to make head against other sources of nocturnal illumination.

Also, it was known that great latitude must be allowed investors in an enterprise generally prophesied to be doomed to failure. Such investors must have the expectation of unusual profit if their enterprise prove serviceable to the public, to bal-

ance against the certainty of total loss if the general expectation of failure were realized.

The corporation was given power to experiment with quality and price. Whatever course seemed to offer the fairest prospect of profit, it was free to pursue. In view of the undeveloped state of the art involved, no other course could be expected to secure the establishment of the industry. No other course would give investors such hope of financial reward as to induce them to the precarious investment.

Briefly, the governmental purpose was the establishment of gas service if it were physically and commercially possible. It was a wise purpose, and they went the right way about it.

The earlier years of the enterprise were lean years, indeed. Apparatus was experimental and inadequate. There were no meters. The gas company sold gas at first by contract at a price per burner, called a "gas rental." The ease with which the supplier could be cheated invited cheating, and the quarrels over bills that arose from the lack of certain means of measuring the service rendered, made the gas business of those years an irritation, certainly, to all concerned, and probably a demoralization as well.

But in 1817 a small dividend was earned, and the success of the theretofore experimental enterprise appeared assured. Doubtless, the adventurous men who had provided the funds for the enterprise expected in peace to reap the financial reward for their sagacity, as probably already they were reaping in the respect of their fellow citizens a reward for their courageous public spirit. But trouble was brewing for them. Their success bred a desire in others, less courageous, to share the profits of the industry, at that time believed to be prospectively enormous.

The Parliament then perceived that the corporation, which had been invested with the right to occupy the sub-soil of the streets was enjoying therein what was and would continue a de facto monopoly as long as no further parliamentary action was had, and would likely prove highly successful in its business.

The importance of protecting the gas user from the results of wasteful management and inordinate profits was emphasized by a class of investors who sought to share in the profits of an industry they had not had the courage to initiate.

The benefits to flow to all interests, state, citizen and in-

vestor, from creating the gas industry a regulated monopoly and its capital a safe and profitable investment, were not realized, or were ignored.

The Parliament, being not less susceptible, perhaps, than are Parliaments of our own time to the ever fearsome cry of blindness to the people's interest, hastened to give evidence of its interest in the quickest and most obvious way.

The obvious remedy for monopolistic evils being competition in kind, and the danger of unregulated monopoly being emphasized, without intelligent suggestion of the merit of established regulation, competition in kind was established. Competition ran its full course in London. Ten years after the formation of the first gas company there were four companies supplying that part of the city lying north of the Thames. Later there were thirteen gas companies with mains in the streets of London. In many streets there were three lines, and in some streets four lines of rival mains. This competition failed of its purpose. Rates were higher in London and service was poorer than in provincial cities, where the industry was a monopoly. Dividends, when existent at all, were small. Finally the nuisance to the public became intolerable, and in 1860 the Metropolis Gas Act, permitting a districting of the territory, was passed, and competition ended. This was soon followed by gradual amalgamation of the thirteen companies—mainly into two great corporations—one operating north of the Thames and one south of the Thames. From the date of the last amalgamation the political history of the London gas industry is the story of effort to encourage investment in gas shares (for extensions and improvements) and to maintain the least possible selling price for gas consistent therewith. This has been secured in London through the operation of the "Sliding Scale" and "Auction Clauses" established by Acts of Parliament.

I am not given enough time to discuss the various governmental experiments prior to the adoption of the sliding scale principle of control, nor to enter far into the detail of the operation of this admirable device. Briefly, the first purpose of the sliding scale was to encourage investment in the business at the lowest obtainable rates by taking advantage of the competition of the entire unemployed capital of the nation, while stimulating this competition by offering the stock issued for new capital at

auction. The second purpose was to enlist the self interest of owners of gas shares in the effort to reduce rates for gas by providing that the dividends permitted to be distributed—if earned—should vary inversely as the selling price for gas was varied. This plan secured money for improvements at the lowest possible rates, and because of the security of the investment these have been very low. It protected the investor, and resulted in almost unbelievably low prices for gas. This for forty years. The war has temporarily unhinged the scheme, because the great increase in the cost of labor and materials compelled a cost and a selling price at which no dividends are possible under the sliding scale provisions. If the price per ton of gas coal (less credit for residuals) and the price per hour for common labor had been made factors in the formula for controlling the price, as might easily have been and as has been provided in part by an act of the Australian Federal Parliament, the sliding scale would have continued to do justice to public and corporation in this time of war, as during the last forty odd years of comparative peace.

All British gas companies, not operating under the sliding scale, have to go to Parliament for power to raise new capital, and therefore at irregular intervals come under governmental investigation and regulation.

This is briefly and broadly the political history of the gas industry in Great Britain in so far as that history has to do with the regulation and protection of gas companies, and the encouragement of extension of gas service. It is not necessary to my purpose to discuss the tendency to municipal purchases of gas undertakings, which was quite pronounced about twenty-five years ago, but has had little force for many years.

America, in the main, escaped the evils of competition in gas supply in the earlier years of the industry, but this was not through intelligent governmental efforts at regulation and protection, and it was at the cost of all the ills that come with the exercise of an unregulated de jure monopoly. Indifference on the part of the servants of the monopolistic corporation, neglect of effort to reduce cost of service so long as dividends were earned, on the part of the owners—irritation born of suspicion of all this on the part of the buyer, and, worst of all, suspicion, and angry, unreasoning charges of dishonest metering—of these is unregulated monopoly the fruitful mother. It is to the credit of

the men who controlled the American gas industry through the monopolistic days that there was little justification for charges of indifference and inefficiency—as there never was any justification for charges of dishonest metering.

American cities found it generally necessary to the first enlistment of capital in the local establishment of the industry to grant monopolistic rights for limited period. Rarely, there was a quality provision in these early franchises. As these franchises expired they were renewed but generally without the monopolistic feature and generally with unelastic regulatory clauses of varying character included. The owners had necessarily to take practically what renewal terms were offered them, and some were taken with great misgiving. But the great growth in population of American cities and the greater growth in the sales of gas—mainly due to the intelligent persistence of gas companies to develop its use as fuel—has enabled these companies to maintain a measure of prosperity through a period of rising costs and of generally lowering income per unit of product.

About the year of 1880, the so-called Lowe Water Gas Process for making a superior quality of gas from anthracite coal or coke and the then otherwise valueless distillates of petroleum was invented and became the ground for the formation of many companies in competition with others already in the field. These competing companies have all been combined with their one time competitors. There was, at the time, a wastage of capital through the formation of these competing companies, but by the increase in use of gas, since realized, the apparatus, mains, etc., of the combined companies have become necessary to the service.

The above brief and rough sketch of the history of the gas industry shows, I think, that as a factor in the development of home comfort and street safety it has had some pretty crude treatment. Yet the gas companies generally have been able to earn dividends and the citizens have had good service. It has been a growing business, and, like a growing boy, has been able to survive the diseases and spankings of infancy and childhood.

The industry, and the company and governmental effort to make the industry "an effective instrument for the service of the individual citizen," have now a perspective. We may see the good accomplished, the mistakes made.

It is too late to prevent the ills consequent upon the early mistakes, but most of these mistakes have run their course and no longer hinder progress. We may learn somewhat from them. The effort of governing bodies, as directed toward gas undertakings, though often blundering, and sometimes vengeful, has generally had the right purpose—the purpose to secure and to continue, first, gas service; second, low-priced gas service, and finally high grade gas service, at as low cost to the user as possible. Through such encouragement as has been given the industry, it has been sought to secure a measure of relief, of easement of the labors of the people. More comfort, less labor, in the home and in the shop. More safety on the streets at night. More money on hand after bills have been paid. Wiser treatment would have resulted in more accomplishment. But the purpose at all periods, though not in all individual cases, has been the advancement of the general good. The methods too often have been harsh; almost uniformly, in this country, they have been rigid. But now we have in commission control an elastic medium, uniting the corporation and the public interest, and from such control we may, and do, expect continued development of the great industry and the best practicable service to the public at the lowest possible cost—long strides toward reaching the goal established by Mr. Fisher's pronouncement.

What must be done to insure the realization of this expectation—to insure that gas companies shall be and continue such "effective instruments" as Mr. Fisher defines—is our problem in so far as we have to do with public utility commissions, or with the operation of gas properties. Our answer has to do first with the provision of plant.

An adequate generating plant and a system of street mains that reaches the dwelling of every citizen within the limits of Mr. Fisher's "organized community" who desires gas service and is able and willing to pay the cost of rendering it to him, are essential parts of an "effective instrument for the service of the individual citizen," and "for the development of the community."

Since the first step toward effective gas service is the provision of a suitable and adequate plant, and since capital is necessary to such provision, gas companies must have means of raising capital as needed for extensions and improvements, or they

will not be able to perform the functions which Mr. Fisher characterizes as a municipality's "primary obligation to secure."

And here we must realize the great shift of responsibility for the development of the industry that has come with the creation of public utility commissions.

When character of service and price of gas were under its own control, a gas company, accepting a franchise, accepted an obligation to provide and maintain a plant adequate to the demand for the service it supplied in the community it served. Its obligation was to be ready for the demand as it came, if reasonably foreseeable, and to get ready with dispatch for unforeseeable demands. The proper performance of these duties is a very serious matter. On it depends some measure of the welfare of millions of people—and the security of millions of invested savings of scores of thousands of people. Since the creation of public utility commissions, endowed with the sole power of control of rates and capitalization, the obligation of a gas company to be ready to supply gas to all in its territory willing to pay the cost of service is no longer unqualified. It is obvious that as the control of the character of service and price of gas have now been taken from the gas companies, the companies themselves cannot any longer create the conditions necessary to insure such profits as will invite capital to the enterprise. The obligation to provide a plant adequate to the demands that may be made upon it is now conditioned upon the opportunity being insured the company to earn and divide among its stockholders such profits as shall make its securities a desirable investment in a competitive money market. This opportunity is now dependent on commission action. It is now therefore the duty of a commission to determine and order that combination of character of service and price of gas which will be so prophetic of profits as to command the capital necessary to enable gas companies to meet the demands upon them. In the view of the gas industry, and in view of Mr. Fisher's pronouncement, this is the great significance of the change from company to commission control.

No man—present stockholder or other—is required or may be forced to provide the necessary capital; he must be persuaded. There is but one way to persuade him. It is to make the investment so attractive that capital will seek it. This is in the hands of the commission. The gas company has little to do with it

beyond foreseeing the necessity and presenting its petitions and arguments to the commission. If the commission fails to order such price and conditions of service as will earn the dividends necessary to attract capital in a competitive money market, there will be no capital provided, and there will be no extension of service. There will be a shortage of a necessary service in the community, and the commission will have failed in its most important function. It remains the duty of gas companies to provide such service as is ordered with the least practicable expenditure of labor and material.

The timidity of capital has passed into proverb. In considering the course to be followed, to insure that capital will come to our undertaking, we must remember that men will not invest in an industry which is under a cloud, or with even a remote (if perceived) danger of entire or partial confiscation of property or of profits.

Industries are normally in competition for capital in the money markets of the world. Before capital will flow into a public utility, opportunity must be assured it to earn, without wastage of itself, at least such a measure of return as could be expected from any other use at the time offering. A gas company must have credit of this kind in the money markets of the world or it cannot secure the funds for the extensions that are necessary to maintain and extend the service as the demand for gas increases, and to realize economies as the art advances. A gas company can secure credit only through confidence in its future earning power. Since the most potent of the conditions essential to the earning power of the industry are under the commission's absolute control, the prospective investor, whose money is necessary to make and maintain the gas property as an "efficient instrument," will require before investing to know what the commission has done and is likely to do in the matter. If the investment appeals to him at all, the rate of interest that he will be willing to contemplate will bear some inverse proportion to the assurance of opportunity to earn the rate. Since the interest on the investment is a factor in the price of gas, the more secure the investment the lower the price of gas.

The combination of price and character of service established, must give promise of sufficient gross income to cover all operating expenses, to provide a sinking fund to restore all parts

as they wear out and to retire any parts that become obsolete or inadequate (but, except in the case of limited term franchise companies, not to return any part of the investment to the investor), and leave enough net reasonably to insure ability to pay upon existing and proposed investment the rate of interest the money market at the moment demands from such investment. Failing this, there will be no new investment. This appears obvious.

If I appear to have unduly and with unnecessary iteration emphasized this thought, it is because I so realize that lack of ability to secure capital is the greatest danger to the ability of the gas industry to properly serve the public under commission regulation, and because I so much desire to persuade you that the first step toward what Mr. Fisher characterizes the unescapable "primary obligation" of the municipal government, now can be met only by the commission—and by it only through the establishment and maintenance of such a combination of quality and price as will make and keep the business attractive to free money in a competitive market.

Clearly it is to the interest of public and of investor to prevent any avoidable element of risk, or gambling chance, entering the investment. It is to the general interest—certainly to the public interest—that the investing public should have such confidence in the security of the investment as not to require the hope of abnormal profits to induce it to buy gas shares for extensions of service. This confidence will be strongest and rate of interest and price of gas lowest where previous investment has had protection.

It is impossible to determine universally applicable, or even generally applicable, standards of price, quality of product and character of service best to be established—that combination which will give to the consumer the greatest benefit per dollar paid. The materials of manufacture available for use so differ in kind and cost throughout the country that standards of quality and price best suited for one state or city may be impracticable for another state or city, and costs of operation will vary with the volume of the business. But there are certain general principles governing these and other matters under commission control and applicable to all situations. These should have mention, and I shall make such brief reference to them as my time permits.

Permanence of tenure should be assured to gas companies.

A company of limited life must provide from its earnings a fund to retire at the end of its life all investments made in its property less its prospective selling value, and this provision will correspondingly increase the cost of gas.[1]

The selfish interest of each gas company should be enlisted in the effort for low rates and good service. The public interest in this extends beyond the class of gas consumers—for a low selling price means a low cost, and a low cost means the conservation of the human and material resources of the nation.

In the general interest there should be the establishment of such standards of quality and service as will permit the widest selection of materials and methods of manufacture practicable for the locality and leave the broadest possible scope for the exercise of engineering skill. This will also tend to national conservation, as well as to reduction of costs.

Character of product and quality of service should be established under penalties sufficiently heavy to insure compliance and systems of inspection under competent men should be established adequate to the detection of violations of established regulations.

Established selling prices must be sufficient to permit such a margin of divisible profit as will insure further investment as needed in a competitive money market.

When a gas company seeks to raise new capital for additions or betterments to its plant, it should be compelled to show the necessity of the proposed expenditures and that each dollar of new investment made and securities issued will add a dollar of value to the property. Uniform systems of accounting and reporting should be adopted.

Further than these things regulation should not go. These things having been established, it should be left for the company to work out its own salvation, and it will be found to the general good to encourage hope in the gas man's breast and to permit special effort and special efficiency to reap a special reward, as

[1] Where the price of gas fixed has not yielded the surplus earnings necessary to the creation of a fund for the retirement of the investment in a plant operated under a limited franchise, the commission concerned must in justice and in the general interest, protect the owner from the loss that would follow if the municipality at the expiration of the franchise took advantage of the situation to acquire the property for less than its value, or to impose an unprofitable franchise extension on the company.

under the "sliding scale." It is by leaving with the corporation officials all the latitude consistent with the enforcement of regulations as to standards and rates—all possible initiative—all possible hope of coincidentally serving stockholders and public—that the best and ablest men will be attracted to the service—and the lowest rates assured to the consumer.

The per cent. of return necessary as an expectation to secure the investment of new dollars is the per cent. that for equity and for the accomplishment of purpose must be allowed to be earned on the entire value of the property devoted to the public use; that is, the value in dollars with which the new dollars by their investment are merged.

An industry's credit is dependent in large part on the record of its financial past—on what return, what per cent. of its value, it has been able and permitted to divide. This value then must have an important place in the commission's formula for the determination of the price to be charged for gas.

I wish I might discuss at length the various practiced and proposed methods of arriving at this value of existing properties as a step in the process of determining the cents per thousand cubic feet necessary to include in the price of gas for return on capital, but, though this is of the first importance, time forbids. It is of the first importance to the public because upon the justice of the determination will depend, on the one hand, the ability of the company concerned to raise money for extensions, and, on the other, the ability of consumers to obtain gas at the lowest possible cost.

Though I am not given the time adequately to discuss these various methods of valuation, some of the factors are so important and so far from general agreement that I think I must present them, though at the risk of out-wearing your patience.

After a commission has decided what rate per cent. of profit is necessary to do justice to present investment and to insure future investment, its next step will be the determination of the amount upon which this rate is to be earned. This step is generally called the "valuation" of the property, and it must be taken as one of the preliminaries to the final step—fixing the price.

No man may dogmatize on methods of valuation—there have been too many intelligent differences of opinion to permit that. I give my thoughts on the question with full recognition of this truth.

If the problem concerned a company starting all new, it would be simple. The commission would keep an account of the expenditures of money from whatever source derived, in construction, in the development of the business, or otherwise; of the value of the property acquired other than by purchase, if any; of all issuance of securities for service rendered or for property; and of the interest on each of these during the period of construction and during the period of development to the point of earning the predetermined rate of profit. The sum of these items, less such amount of interest as might be earned during the period of development, would be the value of the property upon which the predetermined rate of profit should be earned.

In the majority of instances of companies of many years' operation this amount of actual and properly to be capitalized investment cannot be determined from the books. Even if the books disclose all capitalized expenditures, they will fail to reveal great numbers of expenditures, some on other than construction account, many on the lesser betterments and extensions made from the funds of the companies, properly capital charges, but not capitalized on the books. Also there may have been expenditures not capital in character but capitalized on the books where loose systems of accounting have prevailed. So in the majority of cases that will come before commissions the properly capitalizable investment cannot be had from the books of account. Under these circumstances the most practicable way of determining the amount upon which the determined rate of interest shall be earned is by inventory and by valuation of inventory, part by part. We are able to inventory and thus to value the physical property within a very small per cent. of accuracy, and having this value for the physical property we may make additions thereto of other items that cost money or securities to provide and that add to the amount upon which interest must be earned, if investment in the property is to be attractive. Among these are working capital and going value, discussed below, banking charges, organization expenses etc., and interest on each item of cost during the period of development to the point of profitable operation. The sum of these items is not the value of the property as this value will be when the price of gas and the resultant earnings are known, but it is a figure upon which reasonably to base the estimate of earnings necessary to do justice to the present

owner, and to make the business attract the savings of others. The real estate we may value at once by comparison with similar properties similarly located. The structures may be inventoried and their costs determined. I think that we can arrive at the cost of structures to the company in no way better than by determination of cost to build—if with physical conditions, such as pavement, rock, grading, etc., as they existed at the time of construction. And I believe that the average prices prevailing over a period of five years will come very near the average of the actual prices paid through the life of the property, as part by part it has been acquired or erected. This would certainly be very nearly true for any period of five years other than the immediate past, with its great advance in the cost of everything, and for which allowance must be made. I believe that this method of determining the figure for value of property in the formula whose solution is to give the price at which gas must be sold, will do justice to the consumer, to the present owner and will be satisfactory to the prospective investor. I do not know of any other method so promising.

There are instances in which franchises have a value for capitalization in the hands of their present owners. These are special cases, too various for general discussion.

I think it is important here to discuss briefly the oft-discussed questions of the effect on value of pavements and of accruing depreciation.

Some courts of high authority, in what I think a rather vague effort to find a basis for a guess at value, have made lists of various compositions of items—so-called "relevant facts"—to be given consideration, though not necessarily to control, in determining the value of the property devoted to the public use. In these lists is included as a factor to be considered the expenditures necessary to build the plant as existing at the time of valuation. This is called "replacement cost."

The existence of pavement on the streets adds materially to the otherwise cost of replacing mains and services. Where this "replacement cost" is used as one of the "relevant facts" to be given consideration, the cost of existing pavement must be included, if "replacement cost" is to have its full and proper influence with the other "relevant facts" on the final mental conception which the advocates of this method form of value. But,

since pavements laid subsequent to the laying of mains now under them have added neither to the investment of the owner nor to life or capacity of the mains, I do not believe it is necessary to include the cost of such pavement in the amount upon which interest must be earned in order to do justice or to insure that confidence in the security of the investment which will result in futher investment, as needed. I hold this view though in some cases courts and commissions appear to have held otherwise. The added cost of operation, due to the existence of pavement with the necessity of occasionally cutting it for repairs to piping and the interest on the cost of mains laid in temporarily unprofitable territory to keep ahead of paving operations, must appear in the formula for determining the selling price of gas.

Another much-disputed question is whether a plant valuation should take into account the so-called, and unfortunately so-called "accrued depreciation." As I see it, a commission properly insisting upon a plant being kept in condition to render 100 per cent. service cannot consistently deduct from the value of the plant as if new, any sum for "accrued depreciation." I hold this view, though in some cases courts and commissions have held otherwise.

"Accrued depreciation" must not be presented as indicating a run down or deteriorated condition for efficiency or for service, for this would be to mislead. Rather it must be regarded as indicating an accruing and not yet matured obligation of the owner of the plant to renew the plant, part by part, when necessary to maintain its efficiency and service-rendering value.

The consuming public's account with the owner of a gas plant stands always properly chargeable with the cost of the plant as if new, because as time elapses between the date when the plant was new and the date it will become necessary to restore any part, the reduction in the period of its useful life, which will be occurring, is offset, coincidently and commensurately, by the accruing obligation of the owner to renew the part when its period of satisfactory service is past. He has this obligation accruing—and he has also, throughout the life of the plant, his full original investment. He cannot escape this obligation as maturing, which in a large plant for some one or more items of construction is a matter of almost daily occurrence, without impairing, and perhaps destroying, the utility and earning capacity

of his entire plant. Nothing in the industry is more certain than the renewal of parts as they wear out. It may be that the owner has wisely set aside each year a certain part of his earnings against the date of renewal of the larger structures. But whether or not he has foreseen and provided for the time of renewal, it will come, and almost daily as it does come, he has to provide the cost from other sources than additional capitalization. Therefore, if we deny to the owner the opportunity to earn interest on the full reproduction value of his plant, that is, its cost if new —his investment—we compel him to devote a part of his investment to the public use without compensation, and we insure that he and they who know of his experience will avoid thereafter any similar investment. He has through the years an investment equal to the reproduction cost of the plant. Through the years he gives to the public a service not inferior to that rendered by a plant entirely new; for the signal for renewal of a part is the immediately prospective inadequacy of the part to continue to give good service. To renew any part while it is still capable of giving good service would be a waste of money and involve an added cost to the consumer. Before making any further investment the owner will require assurance that his earnings through the years will be upon the full amount invested. In return the service given will be as if from a new plant in all other respects similar.

The cost of current maintenance of the plant—of restoring parts as they wear out—is necessarily an operating charge and will appear in the cost of the gas. I believe that all courts and commissions that have considered this question agree in this.

In addition to the physical structures are certain items of cost of establishing an operating gas company properly to be capitalized and return a profit. Among them are working capital—a very tangible thing—and "going value," a so-called "intangible." The amount of each of these items of cost will vary with the extent of the operations of the company and somewhat with other local conditions. If they, or any items of value, are omitted or slighted in making up the total value of a plant, with a resulting total below the fair and reasonable, the rate per cent. of return upon that total earned and divided must be made correspondingly higher before new capital will be interested. Free capital will not move until satisfied that the value with which it is proposed to merge it is having full and fair consideration.

"Going value" is a particularly interesting subject for discussion, and I regret to leave it with such scant mention.

These briefly are my ideas on some of the items in the valuation of a gas property. There is much more to be said of them, and there are other items of importance in our general problem that must have your attention at some time. Among these, and of great importance, is the method of arriving at the probable cost to produce and deliver the gas. Again, I regret not to be able to discuss them all to a conclusion.

So far this discussion of the duties of public utility commissions has comprehended only the conditions of normal times. It is important to consider the duty of state gas commissions to the public and to the gas industry as affected by the unprecedented conditions created by the great war. I believe we will agree that the war has provoked an immediate need for help to tide our industry over the financial rocks and shoals that threaten to cripple it in its hour of greatest usefulness to individual and to nation.

The current rates for gas were fixed under conditions of costs greatly different from the present. In most instances there now are not sufficient earnings for dividends, and in many instances the receipts are not sufficient for the payment of operating costs. Practically nowhere do the earnings support the credit necessary to enable operating companies to meet the demands for new construction or for the renewal of maturing obligations.

The slow and exact processes of commission regulation, entirely proper and to be desired by all concerned in time of peace, must be temporarily abandoned to meet the exigencies of war times. That such exigencies exist is one of the many unfortunate conditions created by the war, and it is a condition which must be recognized and rectified. It is an unusual condition and calls for unusual treatment. The logical remedy appears to be in line with precedents already established—the arbitrary fixing of rates and standards as a war measure by the war-making authority—the Federal Government. The power to declare and carry on war carries with it by implication the power to adopt the measures necessary for the successful prosecution of the war. One of the measures necessary for the successful prosecution of the war is the maintenance of necessary industries. The

industry which we are discussing is essential to the development of the full power of the nation. It cannot be maintained without immediate and radical changes in standards or rates, or both. It cannot be extended to meet the increased demands of war times without assistance.

If the above be sound, this is a matter with which the Federal Government must concern itself. The present duty of state commissions appears to be to sympathetically aid the gas companies so far as may be in their efforts to serve the people as well as conditions permit, in these months of difficulty, and to encourage and second the Federal Government in any action it may take toward maintaining or re-establishing the financial credit of the industry. But, since public utility commissions are directly charged with the responsibility to the people to maintain and develop the industry, protecting the citizen in his right to a gas supply and the supplier in his right to a profit, they are not doing their full duty, unless in the absence of Federal action, or pending Federal action, they take full care of these their charges.

It is probable that at this time no opportunity for investment that does not involve the patriotic motive, or offer a prospect of returns far greater than may he hoped from any public utility stock, will attract capital. It is improbable that free capital can be induced to investment in extensions to gas plants to meet conditions of demand that may cease with the war. Yet, for the certain success of the war, such extensions must be made. Also, if gas companies could, unassisted, raise the funds necessary, it is not just to require of them that they make extensions of plant that will cease to be profitable as soon as the war ends—and may so remain indefinitely. The discussion of this point is academic —for gas companies cannot raise money for such purposes. It is out of their power. The Government, Federal or State, must advance the money. It should be arranged on terms that insure that the gas company concerned ultimately shall repay the full value to it of the governmentally financed extensions.

The British gas companies, naturally having suffered greatly from the war-created conditions in the labor and materials markets, have sought relief in Parliament, and a Parliamentary committee has reported on the matter. The first paragraph of its report reads:

"That, with the view of maintaining in the public interest

the stability of gas undertakings, some provisions should be made for the temporary modification of statutory requirements with regard to price and dividends in the case of gas undertakings whose financial circumstances have been injuriously affected by causes arising out of the war."

The military importance of maintaining the credit of public service industries in this time of war is recognized by Hon. John Skelton Williams, Comptroller of the Currency, who in his annual report to the Congress says:

"The corporations referred to supply light, heat, power and electric railway transportation for passengers and freight. They touch intimately the daily life of the people. . . . . Now they are threatened with ruin. If they are allowed to sink into inefficiency, much of the most important war work of the Government will be crippled or paralyzed.

". . . . It is essential that forbearance and consideration be exercised by the State commissions and municipal authorities, and that the corporations also be permitted to make such additions to their charges for service as will keep in them the breath of solvency, protect their owners against unjust loss, and give them a basis of credit on which they may obtain the funds with which to meet the strain put on them by the Government's needs. The breaking down of these corporations would be a national calamity.

"Because of the gravity of the situation in this regard, I am moved to ask for it the careful attention of the Congress and the public. I am impressed with the importance of early consideration by the Congress of some measure to provide directly or indirectly for advance of funds on some conservative basis to such of these corporations as need help most urgently, so that they can give adequate service to the Government. The remedy would be unusual; but the times are unusual."

By Secretary McAdoo in a letter to the President:

"Our public service utilities are closely connected with and are an essential part of our preparations for and successful prosecution of the war, and the unfavorable tendencies which the accompanying papers reveal may most effectively be checked, wherever they may be found to exist, and the needed relief obtained, only by prompt action on the part of the respective local authorities.

"I earnestly hope that you may feel justified in expressing the conviction that the vital part which the public utilities companies represent in the life and war-making energy of the nation ought to receive fair and just recognition by State and local authorities."

By President Wilson in a letter to Secretary McAdoo:

"I fully share the views you express regarding the importance of the public utilities as a part of our national equipment, especially in war time. It is essential that these utilities should be maintained at their maximum efficiency and that everything reasonably possible should be done with that end in view."

Since the above declarations of authority were written, it has been announced from Washington that the Federal Government will not undertake the fixing of prices of public utility companies. On this subject, and referring particularly to trolley and lighting companies, Mr. Tumulty has recently written the Mayor of New Orleans in part as follows:

"The conditions under which such companies operate in different parts of the country vary by so wide a variation that no common rule, it would appear, or method of relief could be applied to them. And it is the President's judgment that it is imperatively necessary that local and State authorities should take the action necessary for immediate relief."

Therefore, the obligation of protecting the public service industries on this vital point and in this critical hour remains with the State commissions. Mr. Wilson and his aids have amply set out the necessity for action.

The public utility operators confidently expected that the recently formed War Finance Corporation would greatly aid them in overcoming their war-created difficulties of raising money for demanded extensions, but the construction of the language of the bill by the directors of the Corporation and by the Attorney General of the United States has disappointed this expectation. The War Finance Corporation is not able to lighten this portion of the load of responsibility now resting on public utility commissions.

The opportunity for helpful work toward Mr. Fisher's ideal in the office of public utilities commissioner can hardly be overstated, whether in time of war or in time of peace.

The old distrust and antagonism between gas companies and

their customers, distressing to both, were born of misunderstandings. Some measure of misunderstanding is inevitable between the purveyor and purchaser of a commodity that is used as wanted—without coincident knowledge of the amount being used—and paid for as the use is indicated on a device of the purveyor, little understood and altogether unchecked by or for the customer. Such distrust and antagonism have greatly diminished in recent years and must entirely disappear and mutual confidence and co-operation be established, if under wisely administered commission rule with its assurance of justice to seller and purchaser, and its element of hope for all.

The dignity of the office of Commissioner in control of an industry must be in proportion to the importance of the industry's part in the life of the people. A call to take on the duties of a Public Utility Commissioner is a call to an obligation to protect, develop and regulate an industry vast and important to the citizen and to the State; it is a call to a position of great dignity and of the highest potential usefulness.

In the office of Commissioner, bearing the delegated authority of the State—clothed with well-nigh sovereign powers over one of the greatest and most useful industries of modern days, with a large measure of the comfort and safety of millions of people, and the security of hundreds of millions of invested savings depending upon his judgment and good intent, in such a position any man—however great his attainments, however exalted his character, may find full opportunity for the exercise of his highest faculties and the satisfaction of his highest ambitions. It is a position of heavy responsibility to be desired only by men of clear and open minds, who feel in themselves the power of self sacrifice for a cause. Not even on the bench does character more become a man; and whatever we may say of aims to be attained, standards to be adopted, systems to be followed, now that gas companies are under commission rule, we must depend upon the character of the commissioners for escape from the usual deadening effect of the governmental hand on industry and for the success of the effort to make and maintain the public service corporations what Mr. Fisher nominates "effective instruments for the service of the individual citizen and the development of the organized community." There is no place on a public utility commission for a faddist or a demagogue.

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS. II. THE ELECTRICAL CONDUCTANCE OF TRIMETHYL-PARA-TOLYL-AMMONIUM IODIDE IN WATER AND SEVERAL ORGANIC SOLVENTS.*

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ALTHOUGH the theory of electrolytic dissociation has been fully substantiated for dilute aqueous solutions, investigation in the field of non-aqueous solutions has not been attended with such satisfactory results, and laws which have been found to hold for the former have been found to apply only approximately, and in some cases not at all, to the latter. With the progress of investigation, it has become more and more evident that a great deal of systematic research must still be carried out in the field of non-aqueous solutions before a comprehensive and valid theory of solutions can be formulated. As a result of numerous investigations during the past fifteen years, it is now evident that the capacity for dissociation of those substances which are recognized in water as electrolytes occurs more or less distinctly in other solvents; and, further, that the dissociating power of the solvent is related to other of its physical properties. This has been discussed in a previous paper.[1]

The most comprehensive investigation of the applicability of the theory of electrolytic dissociation to non-aqueous solutions has been carried out by Walden,[2] who has made a systematic study of the electrolytic conductivity of solutions in almost

* Communicated by Professor Creighton.

[1] Creighton, H. J .M., JOUR. FRANKLIN INST., **182**, 745 (1916).

[2] Walden, P., *Zeitschr. phys. Chem.*, **54**, 129 (1905).

every type of organic liquid, including representatives of the alcohols, aldehydes, ketones, acids, acid anhydrides, chlorides, bromides, amides, esters, nitriles, thio-cyanates, and nitro-compounds. To facilitate the comparison of the dissociating power of the different solvents and to determine the influence of the constitution of the solvents on electrolytic dissociation, one solute —tetraethyl-ammonium iodide—was employed throughout. The results of this investigation show that the most important relation between the dissociating power of a solvent and its other physical properties, so far discovered, is that which exists between the dissociating power and the dielectric constant of the solvent.

Recently, Davis[3] has studied the electrical conductivity of solutions of fuchsine—a solute containing the benzol nucleus—in a few non-aqueous solvents. His results show that the behavior of solutions of this solute is practically the same as that of solutions of tetraethyl-ammonium iodide in the same solvents.

The present investigation was undertaken to study more fully the electrolytic conductivity of solutions of a different type of solute containing the benzol nucleus, *viz.*, trimethyl-para-tolyl-ammonium iodide.

The solvents employed embrace various types of organic substances exhibiting different constitutive factors, and belong to the following classes of compounds:

1. Water.
2. Alcohols: methyl alcohol, ethyl alcohol.
3. Aldehydes: propyl aldehyde, benzaldehyde, anisaldehyde.
4. Ketones: acetone.
5. Acids: formic acid, acetic acid.
6. Nitriles: propionitrile, benzonitrile.
7. Nitro-compounds: nitromethane, nitrobenzol.
8. Epichlorhydrin.

A number of other solvents were used, but in these the solute was so slightly soluble that the results of the conductivity measurements were of little or no value.

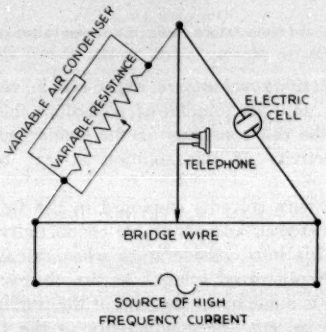
The trimethyl-para-tolyl-ammonium iodide — $C_6H_4N(CH_3)_3I$ —used in the following experiments was readily soluble in water, from which it crystallized in pale yellow plates or needles;

[3] Davis, H. S., *Proc. and Trans.* Nova Scotian Inst. Sci., **13**, 40 (1912).

from dilute solutions in the former form, and from concentrated solutions in the latter. By filtering a solution of the salt through animal charcoal the yellow color was removed, and on allowing the filtrate to crystallize slowly very beautiful colorless crystalline plates were obtained. The salt was purified by repeated recrystallization from water, the influence of recrystallization on the purity of the salt being followed by measuring the specific conductivity of its aqueous solutions.

The Kohlrausch-Ostwald method with the Wheatstone bridge arrangement and the telephone was employed for measuring the

FIG. 1.



electrolytic conductivity of the solutions. The bridge wire was mounted on a marble cylinder and was about 500 cm. in length. The high frequency current was produced by a motor-driven toothed wheel revolving between the pole faces of a magnet. The capacity of the electrolytic cell was balanced by means of a variable air condenser. The conductivity cell was of the Ostwald type, and the size of the electrodes was varied with the nature of the solution used. The platinum electrodes were platinized. The arrangement of the apparatus is shown diagrammatically in Fig. 1. The thermostat was heated electrically, and by means of an electric regulator the temperature could be kept constant within 0.01°.

Below are given the symbols employed in this paper:

v = the number of liters which contain one mole of the solute;

t = the temperature of the experiment in degrees Centigrade;

κ_0, κ_{18} and κ_{25} = the specific conductivity of the solvent at $t = 0°$, $t = 18°$, and $t = 25°$;

κ' = the specific conductivity of the solution;

$\Lambda = (\kappa'_t - \kappa_t)\, v \cdot 10^3$ = the equivalent conductivity of the solution after being corrected for the conductivity of the pure solvent;

Λ_∞ = the equivalent conductivity at infinite dilution;

$\alpha = \dfrac{\Lambda_v}{\Lambda_\infty}$ = the degree of dissociation of the electrolyte;

$k = \dfrac{\alpha^2}{(1-\alpha)_v}$ = the dissociation constant (Ostwald);

ε = the dielectric constant of the solvent at 20°;

$c = \dfrac{\Lambda_v^{t_2} - \Lambda_v^{t_1}}{(t_2 - t_1)\Lambda_v^{t_1}}$ = the temperature coefficient of equivalent conductivity.

All conductivity values are expressed in reciprocal ohms.

A 0.02 *n*. aqueous solution of potassium chloride was used to determine the cell constants of the conductivity vessels, the specific conductivity of this solution at 25° being taken as 0.002768.[4]

Since the pure solvents employed in the following experiments often possessed an appreciable conductivity, it was necessary to take this into consideration when calculating the conductivity of the dissolved solute. As the observed conductivity of the solution is made up of the sum of the conductivities of the solute and the solvent, the conductivity of the former may be ascertained by subtracting from the measured specific conductivity of the solution the specific conductivity of the solvent.

In most cases in the tables which follow, the limiting value of the equivalent conductivity, Λ_∞, has been calculated by means of the formula[5]:

$$\Lambda_\infty = \frac{\sqrt[3]{v_2} \cdot \Lambda_2 - \sqrt[3]{v_1} \cdot \Lambda_1}{\sqrt[3]{v_2} - \sqrt[3]{v_1}}$$

In a few cases it has been ascertained by extrapolation of the curve showing the change in the equivalent conductivity with dilution.[6]

[4] Findlay, A., "Practical Physical Chemistry," p. 181 (1914).

[5] Kohlrausch-Holborn, "Leitvermögen der Elektrolyte," p. 107 (1898).

[6] Ostwald-Luther, "Physiko-Chemische Messungen," p. 481 (1910).

I. WATER:

The water used for the preparation of the aqueous solutions of trimethyl-para-tolyl-ammonium iodide was purified by the method of Jones and Mackay,[1] and had a specific conductivity of 1.8×10^{-6}. It was kept in bottles which had been employed for years for this purpose, and measurements from time to time showed that even after standing for several weeks in these bottles the conductance of the water did not change appreciably.

Trimethyl-para-tolyl-ammonium iodide was found to be readily soluble in water, producing a solution with a pale yellow color. The conductivity of these solutions was measured at 25°, and 0°. The results obtained are recorded in Table I.

TABLE I.

$\kappa_{25} = 1.867 \times 10^{-6}$.

$t = 25°$ $v =$	29.31	58.62	117.24	234.48	468.96	937.92	1875.84	∞
$\kappa' \times 10^3 =$	3.202	1.686	0.8761	0.4513	0.2308	0.1182	0.06085	
$\Lambda =$	93.79	98.72	102.5	105.4	107.4	109.2	110.7	
$\Lambda_\infty =$	....	117.4	116.6	115.1	116.0	116.2		116
$\alpha =$	0.809	0.851	0.884	0.909	0.926	0.941	0.955	1.00
			$\kappa_0 = 2.0 \times 10^{-6}$.					
$t = 0°$								
$\kappa' \times 10^3 =$	1.698	0.9031	0.4667	0.2390	0.1229	0.06350		
$\Lambda =$	49.71	52.87	54.49	55.57	56.68	57.69		
$\Lambda_\infty =$	....	60.8	61.4	60.9	61.6			61
$\alpha =$	0.815	0.867	0.893	0.911	0.929	0.946		1.00
$c_{0-25} =$	0.0355	0.0347	0.0352	0.0359	0.0358	0.0357	...	0.0361

Mean temp. coeff. = 0.0355

In Fig. 2 the cube roots of the concentrations (*i.e.*, $\frac{1}{\sqrt[3]{v}}$, which represents the reciprocal mean common interval of the electrolytic molecules) are plotted as abscissæ against the corresponding equivalent conductivities as ordinates.

As is to be expected, the data contained in Table I show that trimethyl-para-tolyl-ammonium iodide, like other tetra-substituted ammonium salts, is largely dissociated at moderate dilutions. Like the majority of strong electrolytes, the dissociation constant of trimethyl-para-tolyl-ammonium iodide, as calculated from Ostwald's dilution law, varies with the concentration of the solution (see Table II).

[1] Jones, H. C., and Mackay, E., *Amer Chem. J.*, **19**, 283 (1897).

The theoretical grounds for the apparent break-down of the dilution law in the case of strong electrolytes have been the source of much investigation, and as a result it is now generally conceded that the law of mass action will have to be modified or supplemented. Values for the degrees of dissociation of strong electrolytes, derived from conductivity measurements, may be incorrect, owing to the fact that the mobility of the ions cannot be assumed constant, on account of the change of ionic friction with variation in concentration. Jahn[8] has shown that the degrees of dissociation of strong electrolytes derived from conductivity data are too high. On the other hand, the deviation of strong electrolytes from the dilution law may be ascribed to certain chemical causes, such as the formation of inner complexes (the addition of undissociated molecules of the electrolyte to its ions), which, as the results of the investigations of Bredig,[9] Noyes,[10] Steele,[11] and Donnan, Bassett and Fox,[12] show, probably occurs even in solutions of salts of the alkali metals, while in solutions of salts of less electro-positive metals the formation of these complexes has been established beyond doubt. Biltz[13] has arranged the univalent ions according to their tendency to form inner complexes in the following order, this tendency increasing from left to right:

$$Cs^+,\ Rb^+,\ K^+,\ NH_4^+,\ Na^+,\ Li^+,$$
$$NO_3^-,\ Cl^-,\ Br^-,\ F^-,\ I^-.$$

In view of the position of the ammonium and iodine ions, it might well be expected that trimethyl-para-tolyl-ammonium iodide would give results which are not in accordance with the dilution law. Another cause to which failure of the dilution law may be due, is the union of the ions of the electrolyte with the solvent, which phenomenon has been very fully studied by Jones and his co-workers.[14]

Several empirical formulæ have been proposed to express

[8] Jahn, H., *Zeitschr. phys. Chem.*, **33**, 545 (1900).
[9] Bredig, G., *Zeitschr. phys. Chem.*, **13**, 262 (1894).
[10] Noyes, A. A., *Ibid.*, **36**, 63 (1901).
[11] Steele, B. D., *Ibid.*, **40**, 722 (1902).
[12] Donnan, F. G., Bassett, H., and Fox, J. J., *J. Chem. Soc.*, **81**, 944 (1902).
[13] Biltz, W., *Zeitschr. phys. Chem.*, **40**, 185 (1902).
[14] Jones, H. C., JOUR. FRANKLIN INST., **176**, 479, 677 (1913).

the relation between the degree of dissociation $\left(\alpha = \frac{\Lambda_v}{\Lambda_\infty}\right)$ and the concentration for strong electrolytes. That of Rudolphi, [15] which differs from the dilution law in that the square root of the dilution is substituted for the dilution, has the form:

$$\frac{\alpha^2}{(1-\alpha)\sqrt{v}} = k_1$$

According to van't Hoff,[16] the ratio of the cube of the ionic concentration to the square of the concentration of the undissociated molecules is constant, *i.e.*,

$$\frac{\alpha^3}{(1-\alpha)^2 v} = \text{constant}$$

or simplified,

$$\frac{\alpha^3}{(1-\alpha)\sqrt{v}} = k_2.$$

It has been suggested by Storch[17] that a general expression in the form

$$(\alpha c)^n = k_3 (1-\alpha) c,$$

or

$$\frac{\alpha^n}{(1-\alpha)\, v^{n-1}} = k_3$$

be employed, the exponent n being varied as required with different electrolytes. The values calculated for trimethyl-para-tolyl-ammonium iodide with these formulæ, as well as those obtained with the dilution law, are given in Table II, and although the values are more constant (especially in the case of the Storch formula) than those given with the dilution law, nevertheless their theoretical basis is unexplained.

TABLE II.

Values for k for trimethyl-para-tolyl-ammonium iodide at 25°.

v	α	$k = \frac{\alpha^2}{(1-\alpha)v}$.	$k_1 = \frac{\alpha^2}{(1-\alpha)\sqrt{v}}$.	$k_2 = \frac{\alpha^3}{(1-\alpha)\sqrt{v}}$.	$k_3 = \frac{\alpha^n}{(1-\alpha)v^{n-1}}$, $n = 1.40$.
24.31	0.809	0.117	0.633	0.495	1.01
58.62	0.851	0.083	0.635	0.473	1.07
117.24	0.884	0.058	0.622	0.433	1.08
234.48	0.909	0.039	0.593	0.387	1.08
468.96	0.926	0.025	0.535	0.309	1.04
937.92	0.941	0.016	0.490	0.255	1.01
1875.84	0.955	0.011	0.468	0.229	1.02
				Mean:	1.04

[15] Rudolphi, M., *Zeitschr. phys. Chem.*, **17**, 385 (1895).

[16] van't Hoff, J. H., *Ibid.*, **18**, 300 (1895).

[17] Storch, L., *Ibid.*, **19**, 13 (1896).

Since, according to Kohlrausch's law of the independent migration of ions, the equivalent conductance of an electrolyte at infinite dilution is equal to the sum of the individual conductances of its ions, *i.e.*,

$$\Lambda_\infty = l_c + l_a$$

it follows that at 25° the conductance of the trimethyl-para-tolyl-ammonium ion is

$$\Lambda_\infty = l_{C_7H_7N(CH_3)_3}{}^+ + l_I{}^- = 116$$
$$l_I{}^- = 75.7^{15}$$
$$l_{C_7H_7N(CH_3)_3}{}^+ = 40.3$$

II. ALCOHOLS.

As representatives of this class of solvent, methyl and ethyl alcohols were employed.

The small electrolytic conductivity of these alcohols indicates the presence of ions which are probably formed in the manner illustrated by the following equations:

$$R.OH \rightleftharpoons (RO)^- + H^+;$$
$$R.OH \rightleftharpoons R^+ + (OH)^-;$$
$$R.OH \rightleftharpoons R^+ + H^+ + O^{--}.$$

Methyl Alcohol.

The methyl alcohol ("Kahlbaum") was dried for a long time over lime and then purified by fractional distillation, the portion boiling at 65.8° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were slightly yellow in color. The results of the conductivity measurements of solutions of the electrolyte in this solvent are given in Table III.

TABLE III.

$\kappa_{25} = 1.31 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.060	1.142	0.6164	0.3228	0.1700	0.0888	0.0460	
$\Lambda =$	65.9	73.0	78.5	82.3	86.4	89.6	91.5	
$\Lambda_\infty =$	100.1	99.6	97.0	102.1	101.8	99.0		100
$\alpha =$	0.66	0.73	0.79	0.82	0.86	0.90	0.92	1.00

The variation of the equivalent conductivity of trimethyl-para-tolyl-ammonium iodide in methyl alcohol with concentration is expressed graphically in Fig. 2.

[15] Washburn, E. W., "Principles of Physical Chemistry," p. 214 (1915).

Ethyl Alcohol.

The ethyl alcohol was dried over anhydrous copper sulphate and purified by fractional distillation, the portion boiling at 78.4° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were slightly yellow in color. The results of conductivity measurements of the electrolyte in this solvent at 25° and 0° are given in Table IV.

TABLE IV.

$\kappa_{25} = 4.331 \times 10^{-7}$.

$t = 25°$ $v =$	16	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	1.283	0.7514	0.4333	0.2480	0.1396	0.0758	0.0396	0.0208	
$\Lambda =$	20.53	24.03	27.70	31.69	35.63	38.61	40.15	41.78	
$\Lambda_\infty =$	....	(41.9)	46.9	50.8	50.1	46.0	48.1		48
$\alpha =$	0.43	0.50	0.58	0.66	0.74	0.80	0.84	0.87	1.00
$t = 0°$	$\kappa_0 = 3.777 \times 10^{-7}$.								
$\kappa' \times 10^3 =$	0.7410	0.4393	0.2580	0.1475	0.0819	0.0451	0.0239	....	
$\Lambda =$	11.85	14.05	16.49	18.83	20.86	22.89	24.07	....	
$\Lambda_\infty =$	....	25.8	27.9	28.7	30.7	28.6	....		28
$\alpha =$	0.42	0.50	0.59	0.67	0.75	0.82	0.86	....	1.00
$c_{0-25} =$	0.0293	0.0284	0.0272	0.0273	0.0283	0.0275	0.0267	....	0.0285
	Mean temp. coeff. = 0.0278								

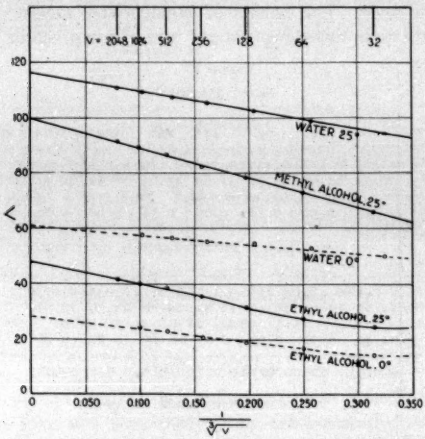
The variation of the equivalent conductivity of the electrolyte in ethyl alcohol with change in concentration is expressed graphically in Fig. 2.

Of the different physical properties of a solvent which influence its dissociating power, by far the most important is the dielectric constant. According to the Nernst[19]-Thomson[20] hypothesis, there exists between these two properties a close parallelism. The researches of Dutoit and Aston [21] have led these investigators to conclude that only those solvents which are highly associated possess dissociating power, while Dutoit and Friderich[22] have come to the conclusion that the electrolytic conductivity of a solute in a non-associated solvent is zero. Regarding the influence of the association of a solvent on its dissociating

[19] Nernst, W., *Zeitschr. phys. Chem.*, **13**, 535 (1894).
[20] Thomson, J. J., *Phil. Mag.* (v), **36**, 313 (1893).
[21] Dutoit, P., and E. Aston, *Compt. rend.*, **125**, 240 (1897).
[22] Dutoit, P., and L. Friderich, *Bull. Soc. Chim.* (3), **19**, 321 (1898).

power, it should be pointed out that solvents which are largely associated invariably have high dielectric constants. The reverse is not true, however, for many solvents with high dielectric constants are not associated.

FIG. 2.



How far the results obtained at 25° for solutions of trimethyl-para-tolyl-ammonium iodide in water (which may be regarded as the first representative of the homologous alcohol series), methyl alcohol and ethyl alcohol are in agreement with these conclusions will be seen from the data given in Table V.

TABLE V.

Solvent.	Degree of Association.[33]	Dielectric constant. ε	Λ_∞	Dissociation of $C_7H_7N(CH_3)_3I$ at v =		
				32	1024	2048
				per cent.	*per cent.*	*per cent.*
Water, HOH	3.81	81.7[34]	116	82	94	96
Methyl alcohol, CH_3OH	3.43	32.5[34]	100	66	90	92
Ethyl alcohol, C_2H_5OH	2.74	25.4[35]	48	50	84	87

[33] Ramsay, W., and J. Shields, *Zeitschr. phys. Chem.*, **12**, 468 (1898).
[34] Drude, P., *Ibid.*, **23**, 308 (1897).
[35] Walden, P., *Ibid.*, **70**, 573 (1910).

It will be observed that these three solvents are able to dissociate trimethyl-para-tolyl-ammonium iodide to a considerable extent, and that the nearer the alcohol stands to water as the first representative of the series, the smaller are the increases in the degree of dissociation between $v = 32 - 1024$:

for water, $\alpha_{1024} - \alpha_{32} = 12$
for methyl alcohol, $= 26$
for ethyl alcohol, $= 37$.

These differences in the increments show that the value for the degree of dissociation of the electrolyte increases more rapidly with dilution the further the alcohol stands from water. Further, it will also be seen that the value for the equivalent conductivity at infinite dilution is greater the nearer the alcohol stands to water.

III. ALDEHYDES.

As representatives of this class of compounds propyaldehyde, benzaldehyde and anisaldehyde were employed.

According to Walden,[26] the auto-ionization of aldehydes, the occurrence of which is indicated by their small electrolytic conductivity, may be brought about by a molecular rearrangement:

$$R.\,C\begin{matrix}O\\H\end{matrix} \rightleftharpoons R_{-H}{:}C\begin{matrix}OH\\H\end{matrix},$$

with the subsequent occurrence of amphoteric dissociation:

$$R_{-H}{:}C\begin{matrix}OH\\H\end{matrix} \rightleftharpoons \left(R_{-H}{:}\begin{matrix}\\H\end{matrix}\right)^{+} + (OH)^{-},$$

and

$$R_{-H}{:}C\begin{matrix}OH\\H\end{matrix} \rightleftharpoons \left(R_{-H}{:}C\begin{matrix}OH\\\end{matrix}\right)^{-} + H^{+}.$$

Propylaldehyde.

The aldehyde was purified by fractional distillation, the fraction boiling at 68.5° being used for the conductivity measurements. Solutions of trimethyl-para-tolyl-ammonium iodide in this solvent were of a yellow-brown color. The color of these solutions decreased in intensity on standing, but their conductivity did not exhibit a corresponding change.[27] In Table VI are recorded the results of the conductivity measurements at 25°.

[26] Walden, P., *Zeitschr. phys. Chem.*, **46**, 137 (1903).

[27] Walden observed a similar phenomenon with solutions of tetra-ethyl-ammonium iodide in propylaldehyde: *Zeitschr. phys. Chem.*, **54**, 147 (1905).

TABLE VI.

$\kappa_{25} = 0.98 \times 10^{-6}$.

$t = 25°$ $v =$	64	128	256	512	1024	∞
$\kappa' \times 10^3 =$	1.055	0.5904	0.3415	0.1809	0.0984	
$\Lambda =$	67.50	75.43	87.16	92.11	99.78	120[28]
$\alpha =$	0.56	0.63	0.73	0.77	0.83	1.00

The change in equivalent conductivity with concentration is shown graphically in Fig. 3.

Benzaldehyde.

The benzaldehyde employed in the following measurements was purified by crystallization and distillation, and had a boiling point of 179°. Trimethyl-para-tolyl-ammonium iodide was found to be fairly soluble in this solvent. The solutions were of a reddish-brown color. The results of conductivity measurements at 18° and 25° are given in Table VII.

TABLE VII.

$\kappa_{25} = 1.93 \times 10^{-7}$.

$t = 25°$ $v =$	64	128	256	512	1024	∞
$\kappa' \times 10^3 =$	2.522	1.512	0.8695	0.4762	0.2633	
$\Lambda =$	16.14	19.33	22.20	24.28	26.20	
$\Lambda_\infty =$	31.6		33.3	32.2	33.5	33
$\alpha =$	0.49	0.59	0.67	0.74	0.79	1.00
			$\kappa_{18} = 1.70 \times 10^{-7}$.			
$t = 18°$.						
$\kappa' \times 10^3 =$	2.288	1.344	0.7841	0.4304	0.2327	
$\Lambda =$	14.63	17.18	20.03	21.95	23.66	
$\Lambda_\infty =$	27.0		31.0	29.3	30.0	29
$\alpha =$	0.50	0.59	0.69	0.76	0.82	1.00
$c_{18-25} =$	0.0147	0.0180	0.0155	0.0152	0.0153	0.0197
		Mean temp. coeff. = 0.0157				

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 3.

Anisaldehyde.

Owing to our supply of anisaldehyde being very limited, purification was not attempted; however, its specific conductivity indicated a high degree of purity. Its boiling point was 248.2°.

[28] This value was derived by graphic extrapolation.

Trimethyl-para-tolyl-ammonium iodide was found to be readily soluble in this solvent, the solutions being almost colorless. The results of the conductivity measurements at 25° are given in Table VIII.

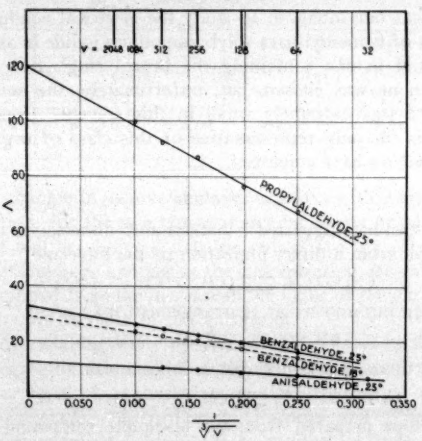
TABLE VIII.

$\kappa_{25} = 2.229 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	∞
$\kappa' \times 10^3 =$	2.006	1.211	0.7045	0.3790	0.2284	
$\Lambda =$	6.35	7.61	8.73	9.65	10.55	
$\Lambda_\infty =$	12.4	13.0	13.2	13.6		13
$\alpha =$	0.49	0.59	0.67	0.74	0.81	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 3.

FIG. 3.



For the purpose of comparison, the percentage dissociation at different dilutions of trimethyl-para-tolyl-ammonium iodide in propylaldehyde, benzaldehyde and in anisaldehyde at 25°, together with the dielectric constants of these solvents, is given in Table IX. As in the case of alcohols, it will be observed that a parallelism exists between the extent of the dissociation of the

solute at a given dilution and the magnitude of the dielectirc constant. The degree of association of each of these solvents is fairly small.

TABLE IX.

Solvent.	Dielectric Constant.	$\wedge_\infty$	Dissociation of $C_7H_7N(CH_3)_2I$ at $v =$		
			64	256	1024
			per cent.	*per cent.*	*per cent.*
Propylaldehyde, C_2H_5CHO	18.5[29]	120	56	73	83
Anisaldehyde, p$-C_6H_4$ (OCH_3, $C{=}O{-}H$)	15.5[30]	13	59	74	..
Benzaldehyde, C_6H_5CHO.....	14.5[31]	33	49	67	79

IV. KETONES.

It was our intention to study the electrical conductivity of solutions of trimethyl-para-tolyl-ammonium iodide in an aliphatic ketone and in one containing the benzol ring. For the latter acetophenone was chosen, but, unfortunately, the solubility of the solute was extremely small in this solvent. Consequently, acetone is the only representative of this class of organic compound that we have employed.

Acetone.

Walden has suggested[32] that the auto-dissociation of acetone may result from a direct ionization of the molecule:

$$CH_3.CO.CH_3 \rightleftharpoons (CH_2.CO.CH_3)^- + H^+;$$

or, first an intramolecular rearrangement may occur:

$$CH_3.CO.CH_3 \rightleftharpoons CH_2{:}C(OH)CH_3,$$

and then this new product may undergo ionization:

$$CH_2{:}C(OH)CH_3 \rightleftharpoons CH_2{:}C(O{-})CH_3^- + H^+.$$

Acetone prepared from the bisulphite compound was employed in the following measurements. This product was allowed to stand for several days over anhydrous copper sulphate, and was then further purified by fractional distillation, the portion

[29] Drude, P., *Zeitschr. phys. Chem.*, **23**, 308 (1897).
[30] Walden, P., *Ibid.*, **46**, 176 (1903).
[31] Thwing, C. B., *Ibid.*, **14**, 286 (1894).
[32] Walden, P., *Ibid.*, **46**, 162 (1903).

boiling between 56° and 57° being used. Trimethyl-para-tolyl-ammonium iodide was difficultly soluble in this solvent, an $\frac{N}{128}$ solution being the most concentrated that could be prepared. All the solutions of the solute in this solvent were colorless. In Table X are given the results of conductivity measurements at 25° and 18°.

TABLE X.

$\kappa_{25} = 0.370 \times 10^{-8}$.

$t = 25°$ $v =$	128	256	512	1024	∞
$\kappa' \times 10^4 =$	7.864	4.570	2.575	1.422	
$\Lambda =$	100.6	117.1	131.7	145.2	
$\Lambda_\infty =$	180.9	187.8	196.7		188
$\alpha =$	0.54	0.62	0.70	0.77	1.00
	$\kappa_{18} = 0.202 \times 10^{-8}$.				
$= 18°$					
$\kappa' \times 10^4 =$	6.466	3.747	2.073	1.117	
$\Lambda =$	82.74	95.87	106.0	114.1	
$\Lambda_\infty =$	146.5	144.9	145.0		145
$\alpha =$	0.57	0.66	0.73	0.79	1.00
$c_{18-25} =$	0.0308	0.0303	0.0346	0.0389	0.042
	Mean temp. coeff. = 0.0336				

The change in equivalent conductivity with variation in concentration, for the two temperatures, is shown graphically in Fig. 4. It will be observed that the curves are not parallel, but slope away from one another as the concentration decreases. This is to be expected from the increase in the value of the temperature coefficient with decrease in concentration.

The dissociating power of acetone, as expressed by the values for the degree of dissociation at the different concentrations, is about what would be expected from the value of its dielectric constant, $\varepsilon = 21.9$[33]. According to Ramsay and Shields[34] its degree of association is 1.26. It is worthy of note that the equivalent conductivity of trimethyl-para-tolyl-ammonium iodide at infinite dilution (and, therefore, the electrolytic mobilities of the ions) in acetone, which is the simplest carbon chain ketone, is very high.

[33] Drude,, P., *Zeitschr. phys. Chem.*, **23**, 308 (1897).
[34] Ramsay, W., and J. Shields, *Ibid.*, **12**, 468 (1893).

V. ACIDS.

As representatives of this class of solvent, formic acid and acetic acid were employed. The association factors of these acids are high, being 3.61 and 3.62, respectively.[35]

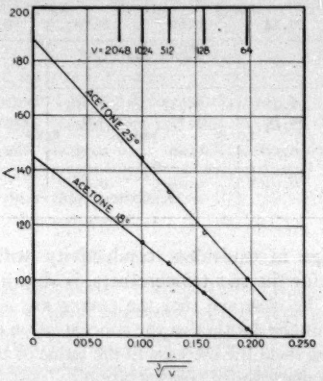
The auto-dissociation of this type of acids is represented by the following equation:

$$R.COOH. \rightleftharpoons RCOO^- + H^+.$$

Formic Acid.

The anhydrous formic acid employed in the following measurements was prepared by the method recommended by

FIG. 4.



Garner, Saxton and Parker.[36] Kahlbaum's formic acid was dried for several days over anhydrous copper sulphate, and then distilled over the same dehydrating agent under a pressure of 120 millimeters of mercury. The distillate was allowed to stand over anhydrous copper sulphate again for twenty-four hours, and distilled a second time at the same pressure. The first third of the distillate was discarded. The portion used in the subsequent measurements boiled at 49.9° under a pressure of 120 millimeters

[35] Ramsay, W., and J. Shields, *loc. cit.*

[36] Garner, J. B., B. Saxton and H. O. Parker, *Amer. Chem. J.*, **46**, 236 (1911).

of mercury. The density of this sample of formic acid was measured at 25°, and a value $d = 1.2136$ obtained.

Trimethyl-para-tolyl-ammonium iodide was readily soluble in this solvent. The freshly prepared solutions were practically colorless, but on standing gradually turned to a deep reddish-brown color.

An $\frac{N}{16}$ solution of the solute was prepared, and its conductivity measured at 25°. Solutions of greater dilutions were obtained in the usual way, by removing one-half of the solution and adding to the remainder an equal volume of pure solvent. It was found that the equivalent conductivity of these solutions increased very rapidly with dilution: $v = 16$, $\Lambda = 41.01$; $v = 256$, $\Lambda = 123.2$; $v = 1024$, $\Lambda = 363.4$. As it was evident from these very high values for Λ at the higher dilutions, that either the solute reacted with the solvent, or that the latter absorbed moisture from the atmosphere, thus greatly vitiating the observed conductivity values, solutions of each desired concentration were prepared by dissolving the requisite amount of solute and the conductivity quickly measured. The values obtained in this way for the equivalent conductivity, together with other data, are given in Table XI, where it will be observed that the Λ values show no such abnormal behavior as those given above. These values when plotted against $\frac{1}{\sqrt[3]{v}}$ lie on a straight line (Fig. 5) which when produced gives for Λ_∞ a value of 90.

TABLE XI.

$\kappa_{25} = 3.01 \times 10^{-4}$.

$t = 25°$ $v =$	16	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.558	1.605	0.937	0.511	0.280	0.146	0.0765	0.0393	
$\Lambda =$	40.93	51.36	59.97	65.41	71.68	74.75	78.33	80.49	
$\Lambda_\infty =$	91.4	93.1	90.0	92.9	86.5	91.9	89.1		90
$\alpha =$	0.45	0.57	0.67	0.73	0.80	0.83	0.87	0.89	1.00

Acetic Acid.

Glacial acetic acid was purified by repeated fractional crystallization, until a product melting at 15.9-16.0° was obtained. The melting point of pure anhydrous acetic acid is 16.7°. Since the presence of one per cent. of water lowers the melting point 2.16°, a sufficient quantity of acetic anhydride was added to our acid to combine with the 0.324 per cent. of water contained

therein. The acid thus obtained had a specific conductivity of 1.69×10^{-7}, a value which agrees closely with that obtained by Walden.[87]

Trimethyl-para-tolyl-ammonium iodide was found to be but slightly soluble in acetic acid, the most concentrated solution that could be prepared being $\frac{1}{256}$ normal. Acetic acid solutions of the solute were almost colorless when first prepared, but on standing gradually turned a reddish-brown. In Table XII are given the results of conductivity measurements at 25°.

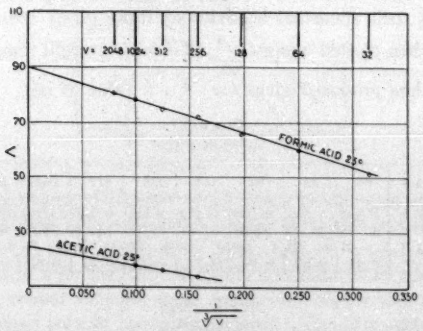
TABLE XII.

$\kappa_{25} = 1.69 \times 10^{-7}$.

$t = 25°$ $v =$	256	512	1024	∞
$\kappa' \times 10^6 =$	5.494	3.189	1.760	
$\Lambda =$	14.06	16.33	18.02	
$\Lambda_\infty =$	25.1	24.5		25
$\alpha =$	0.56	0.65	0.72	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 5.

FIG. 5.



VI. NITRILES.

As representatives of this class of solvent, an aliphatic compound, propionitrile, and an aromatic compound, benzonitrile, were employed.

[87] Walden, P., *Zeitschr. phys. Chem.*, **54**, 159 (1905).

According to Walden,[38] the auto-ionization of nitriles may occur in two ways:

$$R.CN \rightleftharpoons R^+ + CN^-;$$

or a molecular rearrangement may first take place:

$$R.CN \rightleftharpoons (R-H):CNH,$$

followed by the ionization:

$$(R-H):CNH \rightleftharpoons (R-H):CN^- + H^+.$$

Propionitrile.

The propionitrile ("Kahlbaum's") was dehydrated by allowing it to stand for several weeks over anhydrous sodium sulphate, and then purified by fractional distillation. The portion boiling between 97.6 and 98.0° was employed for the following measurements. The results of the conductivity measurements are given in Table XIII.

TABLE XIII.

$\kappa_{25} = 0.281 \times 10^{-6}$.

$t=25°$ $v=$	32	64	128	256	512	1024	∞
$\kappa' \times 10^3 =$	2.165	1.311	0.753	0.414	0.222	0.117	
$\Lambda =$	69.28	83.91	96.38	106.0	113.7	119.8	
$\Lambda_\infty =$	140.2	144.2	143.1	143.3	142.3		143
$\alpha =$	0.48	0.59	0.67	0.74	0.80	0.84	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 6.

Benzonitrile.

"Kahlbaum's" preparation was dried over fused calcium chloride and then purified by fractional distillation under reduced pressure. The solubility of trimethyl-para-tolyl-ammonium iodide in this solvent was very small, and the solutions were of a pale yellow color. The results of conductivity measurements of the solute in this solvent at 25° are given in Table XIV.

TABLE XIV.

$\kappa_{25} = 0.229 \times 10^{-5}$.

$t=25°$ $v=$	128	256	512	1024	∞
$\kappa' \times 10^4 =$	2.279	1.353	0.7605	0.4307	
$\Lambda =$	28.88	34.04	37.77	41.76	
$\Lambda_\infty =$	54.0	52.2	57.0		54
$\alpha =$	0.54	0.63	0.70	0.77	1.00

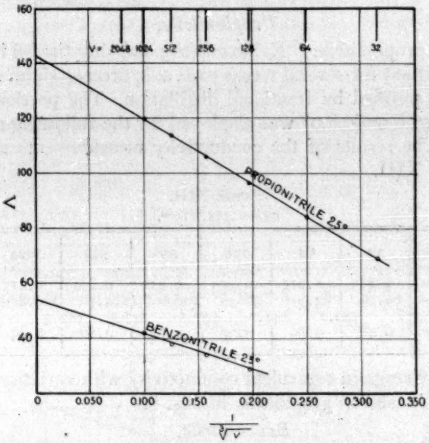
[38] Walden, P., *Zeitschr. phys;. Chem.*, **46**, 155 (1903).

The change in the equivalent conductivity with variation in concentration is shown graphically in Fig. 6.

VII. NITRO-COMPOUNDS.

As representatives of this class of solvent, an aliphatic compound, nitromethane, and an aromatic compound, nitrobenzol, were selected.

FIG. 6.



Regarding the auto-ionization of this type of solvent, Walden[39] has suggested two possibilities: (1) a molecular rearrangement:

$$R.NO_2 \rightleftharpoons (R-H) : NOOH,$$

which is followed by ionization:

$$(R-H) : NOOH \rightleftharpoons (R-H) : NOO^- + H^+;$$

and (2)

$$R.NO_2 \rightleftharpoons R^+ + NO_2^-.$$

Nitromethane.

This solvent[40] was dried for several months over fused cal-

[39] Walden, P., *Zeitschr. phys. Chem.*, **46**, 161 (1903).

[40] We wish to express our indebtedness to Mr. J. R. Hull, of the Department of Chemistry, of Swarthmore College, for the preparation of the nitromethane we used in this work.

cium chloride and then purified by fractional distillation, the portion boiling at 101° being employed. Trimethyl-para-tolyl-ammonium iodide was readily soluble in nitromethane, the solutions having a pale yellow color. The results of conductivity measurements at 25° are given in Table XV.

TABLE XV.

$\kappa_{25} = 1.32 \times 10^{-6}$.

$t = 25°$ $v =$	32	64	128	256	512	1024	2048	∞
$\kappa' \times 10^3 =$	2.275	1.275	0.698	0.369	0.193	0.1007	0.0524	
$\Lambda =$	72.77	81.54	89.22	94.21	98.30	101.8	104.7	
$\Lambda_\infty =$	115.2	118.7	113.4	114.1	115.0	115.8		115
$\alpha =$	0.63	0.71	0.78	0.82	0.86	0.89	0.91	1.00

The variation of equivalent conductivity with change in concentration is shown graphically in Fig 7.

Nitrobenzol.

This solvent was purified by fractional distillation. Trimethyl-para-tolyl-ammonium iodide was fairly soluble in nitrobenzol, the solutions possessing a yellow color. The conductivity of the solute in this solvent was measured at 25° and 18°, the results obtained being recorded in Table XVI.

TABLE XVI.

$\kappa_{25} = 0.327 \times 10^{-6}$.

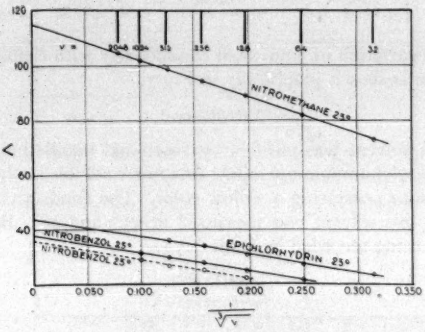
$t = 25°$ $v =$	64	128	256	512	1024	∞
$\kappa' \times 10^4 =$	3.405	1.969	1.096	0.5865	0.3103	
$\Lambda =$	21.77	25.16	27.98	29.86	31.39	
$\Lambda_\infty =$	38.2	38.9	37.1	37.2		38
$\alpha =$	0.57	0.66	0.74	0.79	0.83	1.00
	$\kappa_{18} = 0.201 \times 10^{-6}$.					
$t = 18°$						
$\kappa' \times 10^4 =$	2.991	1.752	0.989	0.5315	0.2858	
$\Lambda =$	19.13	22.40	25.27	27.11	29.06	
$\Lambda_\infty =$	35.0	36.4	34.2	36.5		36
$\alpha =$	0.53	0.62	0.70	0.75	0.80	1.00
$c_{18^\circ - 25^\circ} =$	0.0197	0.0176	0.0153	0.0145	0.0115	

The change in equivalent conductivity with variation in concentration, for the two temperatures, is shown graphically in Fig. 7. It will be observed that the curves are not parallel, but that they slope towards one another as the concentration decreases, as

would be expected from the decrease in the value of the temperature coefficient with decrease in concentration.

For a given dilution it will be observed that the degree of dissociation of trimethyl-para-tolyl-ammonium iodide is considerably greater in the aliphatic than in the aromatic solvent. While the dielectric constant of the former solvent is greater than that of the latter, according to Trouton's rule nitromethane is associated, since its constant is 18.7 instead of 20.65, while, on the other hand, nitrobenzol is not polymerized, since its constant has the value 20.7.

FIG. 7.



VIII. EPICHLORHYDRIN.

As only a very limited quantity of this solvent was obtainable, no attempt was made to purify it. Its low specific conductivity indicated, however, that it was very pure. Trimethyl-para-tolyl-ammonium iodide was found to be very readily soluble in epichlorhydrin, the solutions being of a pale yellow color. In Table XVII are recorded the results of conductivity measurements at 25°.

TABLE XVII.

$\kappa_{25} = 5.367 \times 10^{-7}$.

$t = 25°$ $v =$	16	32	64	128	256	512	∞
$\kappa' \times 10^3 =$	1.255	0.7316	0.4222	0.2392	0.1332	0.0703	
$\Lambda =$	20.08	23.41	27.02	30.62	34.10	35.99	
$\Lambda_\infty =$	..	40.9	44.4	47.5	43.3		44
$\alpha =$	0.46	0.53	0.62	0.70	0.78	0.82	1.00

The change in equivalent conductivity with variation in concentration is shown graphically in Fig. 7.

SUMMARY AND CONCLUSIONS.

1. The conductivity of trimethyl-para-tolyl-ammonium iodide in water and in 13 organic solvents has been measured at 25°. In the case of a few of the solvents, measurements have also been made at a second temperature, and the temperature coefficient of the equivalent conductivity of the solute determined.

2. Like the majority of strong electrolytes, it has been found that trimethyl-para-tolyl-ammonium iodide in aqueous solutions does not follow Ostwald's dilution law. Of the several empirical dilution formulæ investigated, only in the case of Storch's general equation,

$$\frac{a^n}{(1-a)v^{n-1}} = k,$$

has a value been obtained for k which does not vary with the concentration of the solute.

3. The conductance of the trimethyl-para-tolyl-ammonium ion in aqueous solution has been found to be 40.3 at 25°.

4. The equivalent conductivity at infinite dilution, Λ_∞, of trimethyl-para-tolyl-ammonium iodide in the different solvents has been determined by calculation or extrapolation. The values obtained vary from $\Lambda_\infty^{25} = 13$ for anisaldehyde to $\Lambda_\infty^{25} = 188$ for acetone. The magnitude of these values bears a relation to the chemical constitution of the solvent; and it may be stated, generally, that the equivalent conductivity at infinite dilution of the electrolyte, and, therefore, the velocity of its ions, is greater in an aliphatic solvent than in the corresponding aromatic solvent:

	Λ_∞^{25}	
Nitromethane,	115	Nitro-Compounds.
Nitrobenzol,	38	
Propionitrile,	143	Nitriles.
Benzonitrile,	54	
Propionaldehyde,	120	Aldehydes.
Benzaldehyde,	33	

Moreover, for any homologous series, the value for Λ_∞ is greater the nearer the solvent stands to the beginning of the series:

	Λ_{∞}^{25}	
(Water),	116	
Methyl alcohol,	100	Alcohols.
Ethyl alcohol,	48	
Formic acid,	90	
Acetic acid,	25	Acids.

Of the various substituting groups, the influence of the aldehyde group on the magnitude of Λ_{∞} is greatest,[41] while that of the carboxyl group is least:

in $CH_3.C\begin{matrix}O\\H\end{matrix}$	>	$CH_3.NO_2$	>	$CH_3.OH$	>	$CH_3.CO_2H$
$\Lambda_{\infty}^{25}=188$	>	115	>	100	>	25

[41] Walden has shown that the influence of the cyanogen group on the magnitude of Λ_{∞} is even more marked than that of the aldehyde group.

DEPARTMENT OF CHEMISTRY,
SWARTHMORE COLLEGE,
September 16, 1918.

Testing for Fires in Piles of Stored Coal. H. H. STOEK. (Western Society of Engineers through *Electrical World*, vol. 72, No. 4, p. 162, July 27, 1918.)—According to Professor Parr of the University of Illinois, bituminous coal can be stored without appreciable loss of heat value, provided that the temperature is not allowed to rise above 180° Fahr. How close to this temperature a pile should be allowed to heat is largely a matter of judgment, for if the rise appears to be decreasing rapidly, it may be safe to allow it to approach 180° Fahr., whereas if the rise is steady and regular it is wise to load out the pile before the danger point is reached. The time also depends upon the means available for loading out the coal. In a plant equipped with large grab buckets and means for rapidly handling the coal, a higher temperature can be permitted than where a considerable time may be required to load out the coal.

A person in charge of a certain kind of coal under certain climatic conditions will learn where the danger point is, and it is impossible to set any critical temperature that will apply to all coals under varying storage conditions. The only safe rule is to watch the pile closely and get ready to load out the coal when the temperature reaches 150° Fahr. and to move the coal if the temperature reaches 175° Fahr. Common methods for testing coal piles for heat are as follows: Watching when the pile begins to steam; observing the odor, which is that of either burning bituminous matter or burning sulphur; inserting an iron rod into the pile and when drawn out testing it with the hand; inserting a thermometer into a pipe driven in the pile; observing spots of melted snow on the pile.

A NEW THEORY OF PLATE SPRINGS.*

BY

DAVID LANDAU and PERCY H. PARR.

PAPER 2.

In our first paper[1] we made a liberal effort to show the fundamental principles underlying our new theory of plate springs, and to indicate briefly, though succinctly, the irrationality of the old theory. No direct mathematical proof was offered to substantiate our statements regarding the errors of the old theory for it seemed to us that such proof was not demanded; the facts themselves, as marshalled into evidence, being deemed to be, as the lawyers say, *prima facie* evidence of its inaccuracy.

The reader who has followed our exposition with sufficient care will, however, doubtless find some objections and be inclined to take exception to some of the statements as not having been proved; this may be the case, to an even greater degree, with the engineer who has had much experience in the use of plate springs and especially to him who has kept a record, or compiled statistics, of the breakages of spring plates.

Our intention in the first paper was to avoid tediousness in the exposition of this apparently simple but really very complex subject, hence, it was, in some ways, but a foreword to this more complete and prolix exposition. Much, necessarily, had to be left to the present paper; even this one will not include all of the many elements that have to be considered, certain of which must be left for the third and (for the present) concluding paper. We shall preamble the present exposition by a few remarks which have been verified by tests and experience.

Most experienced spring makers have noticed that the short plate is the one which breaks most often on ordinary plate springs; so far then our theory has offered an intelligible—and as we hope to show, ultimately, a true—explanation of the observed facts. On the other hand, there are many exceptions to this breakage of the short leaf. It is a fact beyond contradiction, that with very many springs, other plates break with equal or, in some

* Communicated by the Authors.

[1] This Journal, Vol. 185, April, 1918, p. 481.

rare cases, with even greater frequency than do the short plates. For instance, in a series of endurance tests of several hundreds of springs, made a few years ago, the majority of the breakages occurred in the master leaves; in several cases the intermediate leaves broke, but only in a comparatively small number of cases was the fracture confined to the short leaf. Why should this be so? Indeed, from the exposition of our theory, as given so far, it might be reasonably asked, "If your theory is correct, how is it possible that any plate other than the short one can break first?"

It may also be mentioned as an established fact that many commercial springs, constructed from the point of view of low cost of production combined with reasonable safety in use, are made of ordinary qualities of "carbon spring steel" except for the master leaves, which are made of high-grade "alloy spring steels."

Why this practice if the theory we have so far expounded be correct? And how can we, on the basis of our theory, account for the many apparent exceptions to it? The answers to these questions are fairly simple, but the formal proofs are tedious and long.

In order to allay the desire of the reader to understand the reasons of the apparent—and they are only apparent—discrepancies between our theory and the facts of practice, we shall give a brief "word-picture" first and afterwards proceed to the formal mathematical proof.

There are two principal causes which operate to induce a leaf, in a leaf spring, other than the short one to break first: for the moment we shall name only one of these and that is *the tapering of the ends of the leaves.*

This one cause—*tapering*—produces the most astonishing modifications in the reactions and, of course, the stresses in the leaves. The "life" of the spring is increased or decreased in proportion as this seemingly minor, but really most important, detail is given proper consideration in the design and in the manufacture. Our theoretical investigations and long practical experience justifies our making immediately the definite statement that, *next to the homogeneity of the molecular structure of the finished product, the tapering of the ends of the leaves is of the greatest importance, and in order to obtain the best results in the*

longevity of a plate spring the tapering should be carried out with mathematical exactitude.

We believe that we have, in a very great measure, solved this most important question of tapering on scientific principles, and our researches appear to prove that we have been the first to define the precise effects of tapering and its resultant effect on the strength and life of leaf springs.

Before the publication of the present paper, if anyone had made an inquiry of the engineer, or even of the experienced spring maker, as to what was the effect of tapering the ends of the leaves on the "strength," the "life" or on the "endurance" of a spring, the average answer would have been about as follows: "The tapered-end leaves look better, but are of no particular advantage;" and as confirmatory evidence, if that be needed, "the railroad springs are scarcely ever tapered." A more astute engineer might "guess" that, "the tapered-end leaf is better," but as to why, how, and how much better? he could give no answer. We shall, in fact, show later on that the effect of tapering may be either for the better or for the worse—the good effects produced have limitations, although, in general, tapering is beneficial as compared to no tapering. The mathematical proof is rigorous but not too easy, and an attempt will first be made to give a mental concept of the physical effects.

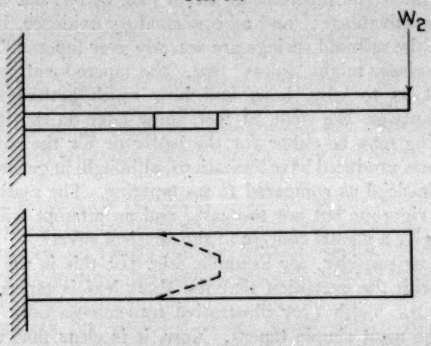
Let us consider, for example, Fig. 10; this is the same as Fig. 3, with the exception that the short leaf is tapered in the plane of the width (for illustrative convenience only we have shown the most simple taper). Now, it is clear that with any given load placed on the end of the short leaf, it will deflect more than it would if it were not tapered. This is a simple and obvious fact which does not seem to require a formal proof but which is of the greatest importance. In other words, the effect of tapering the end of a leaf is to make that leaf, as a whole, more flexible; also, since the leaf still has the same section at the point of maximum stress, namely at the point of encastrèment, the safe load that may be placed thereon still remains W_1, although this load will cause a greater deflection of the short leaf than in the case of a non-tapered leaf. This being granted, we may next consider the effects on the leaf above.

Since the load, W_1, on the end of the short leaf (for convenience it may be taken as the load producing the maximum

allowed stress in that leaf) can only come from the pressure of the plate above on it, it follows therefore that the plate above must also deflect a greater distance when the bottom plate is tapered than when it is not. But, in order to obtain this greater deflection of the plate above we must place a load, W_2, on it which is greater than it was in the cases of the non-tapered bottom leaf shown in Figs. 8 and 9.

Some readers may take exception to the statement that the load W_2 becomes greater in this case; their judgment is not to be questioned here, but we ask them to withhold any contrary opinion until we give the more rigid proof; we ask them to accept, provisionally, our statement that W_2 is greater when the bottom plate, No. 1, is tapered than when it is not. On this basis we will continue further.

FIG. 10.



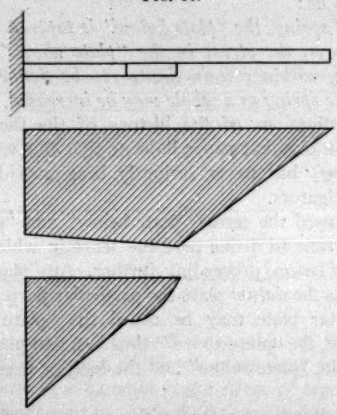
Assuming then that W_2 has now become greater than $4/5\ W_1$ (the value found in our first paper) we see that we have the apparently curious result that *when we taper the end of the leaf below we can increase the safe load on the leaf above,* and, of course, on the spring as a whole—a result that would hardly be expected, much less looked for. This concludes, briefly, the "word-picture" of the principles in question and of which the formal proofs will be given shortly.

To avoid misunderstanding in future expositions concerning tapered-end leaf springs it is to be understood that we use

the word *taper* in its most general sense, except in cases where it is specifically given a limited meaning. A taper, straight or curved, in width only, as in Fig. 10, or a taper in thickness, or any combination of the two, may be assumed to apply with equal force to the discussion.

It seems to us, as the result of our experience of teaching some of these principles to others, that clarity of the mathematical exposition may be gained, and greater confidence placed in the formal reasoning if we place some additional physical illustrations before the reader. Realizing, as we do, the difficulties

FIG. 11.



we had in the earlier years of this investigation, we are prone to expand somewhat our illustrations in order to avoid later dilation. The reader who is so fortunate as to have already obtained a clear mental grasp of our general ideas may skip the next few paragraphs.

Consider again Fig. 10; we have stated that W_2, in this case, is greater than the corresponding W_2 of Fig. 3 for the same value of W_1; suppose then that W_2 instead of being equal to $4/5W_1$, as was the case for Fig. 3, is now equal to, say $9/10W_1$, and let us see what happens to the stress distribution in the two plates. The result of this assumption is shown in Fig. 11, which

is to the same scale as Fig. 8, in which we showed the stress distribution for the two-leaf spring of Fig. 3. The most important result is that the stress in the main, or master leaf, has increased, by about 6 per cent. on an average, and so the metal in this leaf, which is still not stressed as high as that in the short leaf, is, however, being used to much greater advantage. The stress in the short leaf has been increased slightly, in the tapered part, but the difference here is not of great account; at the same time, it is all in the direction of greater load capacity per unit weight of spring; the weight of metal has been reduced, and that which has been left is utilized to greater advantage. The whole effect then may be said to be:

If, in any spring, the "plate below" is tapered in any of the well-known ways, the stress in the "plate above" is increased and, therefore, within certain limits (to be defined later), the safe load on the spring as a whole may be increased.

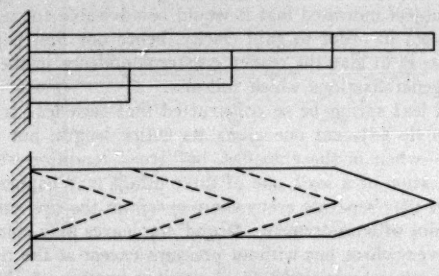
Our investigations of the history of the theory of plate springs given in our first paper indicate that this very important effect (tapering) has never seriously been considered by any previous investigators.

We have used the terms "plate below" and "plate above"; it seems opportune to define here the sense in which we always use these terms before proceeding further. Any plate in a spring may be taken as the *datum* plate for particular purposes, in which case any shorter plate may be called the "plate below" and any longer plate, the "plate above": thus in a two-plate spring, the short plate is the "plate below" and the long or master plate, the "plate above."

We have already seen that with any plate spring composed of non-tapered plates of equal cross section, the stresses in the upper plates are less than those in the lower ones, and we have just shown that the effect of tapering the ends of the lower leaves is to increase the stresses in the upper ones. The question naturally follows—is it possible so to arrange the tapers that the reactions and stresses shall all be equal? The answer is in the affirmative. A spring having these characteristics can be constructed, and is shown in Fig. 12, which really is none other than that of Fig. A of our Historical Introduction. This is the special spring regarding which all of the old and

ordinary formulæ are based, but it is never, or at least very rarely, found in practice. It will be shown later that such a spring made of equal thickness plates and in which the tapers are so made that the moment of inertia is everywhere proportional to the bending moment in the overlap or step, has equal reactions and the stresses are everywhere the same. Theoretically this should be the ideal spring, as it would then carry a load directly proportional to the number of plates; there are other modifying circumstances, however, which will be duly discussed, that prohibit such springs from carrying loads directly proportional to the number of leaves, and such springs, in consequence, are not to be found in general use.

FIG. 12.



Before closing the general description of the physical effects of tapering the ends of the leaves we must push the question a little further and ask: *what is the effect of tapering the plates too much?* The answer is, as we shall prove in due course, that the reactions go on increasing and, after a certain limiting amount of taper, any further tapering will cause the stresses to be greater in the upper leaves than in the lower ones. Since it is usually, from a practical point of view, most important that the master leaf of a spring should not be the first one to fracture, it follows that an excessive amount of tapering is most objectionable. It appears also that the exact details of the tapering are of the utmost importance, and while this is a question which has been altogether neglected from the scientific point of view up to the present, it is necessary to study it with the greatest care in order to obtain the best springs, and it is mainly through the

study of this major detail that we have been able to obtain some of the results indicated in our first paper.

The physical illustrations of the effects of tapering the ends of the leaves can no longer be dealt with by exemplifications and analogy; they would soon grow so complex as to become unintelligible. The following mathematical exposition will clarify the situation.

THE GENERAL THEORY OF LEAF SPRINGS.

Had we followed the usual sequence, the general theory of leaf springs, of which the larger part of the present paper is an exposition, would have been treated in our first paper, but, for reasons already stated the actual complexity of this apparently simple subject indicated that it would be advisable for us to discard custom in order to gain clarity, hence our first paper was written so as to give the reader greater confidence in the mathematical generalizations which follow.

If a leaf spring be so constructed that each leaf is in contact with its adjacent one along its entire length, but without pressure—when in the unloaded, or "free" condition—then, on the application of a load, one of three things may happen. First, the leaves may separate everywhere except at the tips and at the centre point of encastrèment; second, the leaves may continue in contact everywhere but without pressure except at the tips; and third, the leaves may tend to foul one into another, so that there will be pressure acting between the leaves for a greater or lesser part of their length.

Our first paper dealt with the first condition, which is usually of the greatest importance, and a hint was given as to the occasional existence of the other conditions.

The second condition may be considered as the limit of either the first or the third, and so forming the line of demarcation between them.

The first case, carefully expounded by the theory given in our first paper, considered the leaves when subjected to load to remain in contact only at the centre point of encastrèment and at the tips of the leaves: most of the commercial springs, especially those of the cheaper grades, and of the heavy springs used by the railways, fall into this class.

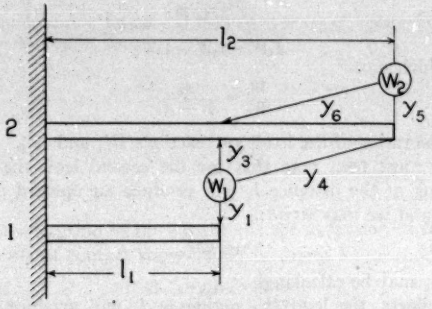
The second case will be examined from the point of view

of it being the limiting case of the first—it is not of much actual importance, but still requires to be considered in order to make the study complete.

The third case is not of common occurrence in practice, nevertheless it is becoming more so, and may occur either through design or through accidents of manufacture. It is of considerable importance, and will, therefore, be considered in due course.

With these preliminary remarks we now proceed to establish the generalization of our theory in as simple a manner as

FIG. 13.



possible. For convenience we will first consider the two lower plates of a spring.

Referring to Fig. 13, the load on the end of plate No. 1, or the reaction between plates Nos. 1 and 2, is W_1. The load on the end of plate No. 2 is W_2.

Considering the bottom plate, No. 1, the load W_1 acting on it will produce a downward deflection which we will denote by y_1, and we may write:

$$y_1 = A_1 W_1$$

where A_1 is a coefficient which may be calculated when we know the section everywhere of plate No. 1.

Now, considering the second plate, the reaction W_1 acting at the distance l_1 will produce an upward deflection, say y_2, at the distance l_1, and we may put:

$$y_2 = A_2 W_1$$

where A_3 is a coefficient which may be calculated when we know the section everywhere of plate No. 2.

Similarly; the load W_2 acting on plate No. 2 at the distance l_2 will produce a downward deflection at l_1 which we may denote by y_6 and we can thus write:

$$y_6 = A_6 W_2$$

where, again, A_6 is a coefficient which may be calculated when we know the particulars of the second plate.

Next, considering the equilibrium of the two plates, it is at once seen that:

$$y_1 = y_6 - y_2$$

or:

$$A_1 W_1 = A_6 W_2 - A_3 W_1$$

from which:

$$\frac{W_1}{W_2} = \frac{A_6}{A_1 + A_3}$$

giving the ratios of the loads or reactions W_1 and W_2.

We must next note that for the second leaf, the reaction W_1 acting at the distance l_1 will produce an upward deflection y_4 at l_2, and we may write:

$$y_4 = A_4 W_1$$

where A_4 may be calculated.

Similarly, the load W_2 acting at l_2 will produce a downward deflection of y_5 at l_2, and we have:

$$y_5 = A_5 W_2$$

where again A_5 is a coefficient which may be calculated.

The total actual deflection then of the two-plate spring at l_2 due to the load W_2, which we shall denote by Y_2, is evidently

$$Y_2 = y_5 - y_4$$

or:

$$Y_2 = A_5 W_2 - A_4 W_1$$

The reasoning, unfortunately, is not too easy, although a careful study of the foregoing, with the aid of the diagram, will show that the question is merely one of equating to equality the upward and downward deflections of the plates, which are produced by the various forces.

Having indicated the method of procedure as applied to the two bottom leaves, we proceed to the general case, and for

this we refer to Fig. 14. It is to be understood that the y's (small y's) refer to the deflections of the individual plates, considered apart from the spring as a whole, and the Y's (capital Y's) refer to the deflection of the "partial springs," thus:

y_{4n} is the upward deflection of the $n+$ 1th leaf at l_{n+1} due to the reaction W_n at l_n;

y_{4n-1} is the upward deflection of the $n+1$th leaf at l_n due to the reaction W_n at l_n;

y_{4n-2} is the downward deflection of the nth leaf at l_n-1 due to the reaction W_n at l_n;

y_{4n-3} is the downward deflection of the nth leaf at l_n due to the reaction W_n at l_n;

Y_n is the downward deflection of the partial spring of n plates at l_n due to the reaction W_n at l_n.

Now let:

$$y_{4n-3} = A_{4n-3} W_n \quad \ldots\ldots (9)$$

$$Y_n = B_n W_n \quad \ldots\ldots (10)$$

and

$$W_{n-1} = C_{n-1} W_n \quad \ldots\ldots (11)$$

then a consideration of the equality of the deflection of the plates at the points of contact shows that:

$$y_{4n-2} - y_{4n-3} = Y_{n-1}$$

or:

$$A_{4n-2} W_n - A_{4n-3} W_{n-1} = B_{n-1} W_{n-1}$$

from which we obtain:

$$\frac{W_{n-1}}{W_n} = C_{n-1} = \frac{A_{4n-2}}{B_{n-1} + A_{4n-3}} \quad \ldots\ldots (12)$$

We also note that:

$$y_{4n-2} - y_{4n-4} = Y_n$$

or:

$$A_{4n-2} W_n - A_{4n-4} W_{n-1} = B_n W_n$$

from which:

$$B_n = A_{4n-2} - A_{4n-4} C_{n-1} \quad \ldots\ldots (13)$$

and these equations give the fundamental relations between the deflections of the individual leaves, those of the partial (and complete) springs, and the ratios of the various reactions.

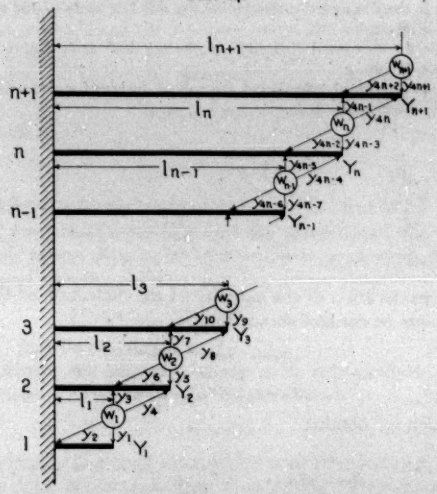
It must be noticed that A_2 (the deflection coefficient for the bottom plate at the encastrèment) is always zero, and that B_1

(the deflection coefficient of the partial spring of one plate only) is always equal to A_1.

The complete relations of a spring can now be calculated, starting at the short plate, called No. 1, and working upwards, as is explained more fully in the succeeding paragraphs.

The A's can all be calculated independently, for they depend solely on the individual details of the various plates: these cal-

FIG. 14.



culations for various cross-sectional variations of the plates will be dealt with fully in a later section of this paper, and for the moment we will assume that all the A's have been determined.

Note that $B_1 = A_1$.

Next put $n = 2$ in equation (12) and we obtain:

$$C_1 = \frac{A_2}{B_1 + A_1}$$

from which C_1 can be calculated.

Then put $n = 2$ in equation (13) and we obtain:

$$B_2 = A_2 - A_1 C_1$$

from which B_2 can be calculated.

Having now calculated C_1 and B_2, put $n = 3$ in equations (12) and (13), giving:

$$C_2 = \frac{A_{10}}{B_2 + A_7}$$

and

$$B_3 = A_9 - A_8 C_2$$

from which C_2 and B_3 are obtained.

Proceeding in a similar manner will give the deflection and reaction coefficients for the complete spring. The work is somewhat tedious but not difficult and, after a few springs have been calculated out, it will easily be seen that the work of arithmetical computation can be systematized so as to minimize the actual amount of labor. It must be admitted, however, that the labor of working out completely, say, a ten-plate "graded"* spring is very considerable, and in practice, where many springs have to be calculated out, a calculating machine is certainly a desirability—almost a necessity.

The above exposition contains the complete theory of the deflection and reaction relations for all leaf springs which are such that the leaves do not tend to foul into one another, and therefore covers, as previously mentioned, the great majority of commercial springs.

We now proceed to details and show how the values for the A's for the various plates are to be derived.

In general terms, if y is the deflection at the distance x from the point of encastrèment, then using the well-known relation:

$$\frac{d^2y}{dx^2} = \frac{M}{EI} \quad \ldots\ldots (14)$$

we have:

$$E\frac{dy}{dx} = \int_o^x \frac{M}{I}\,dx \quad \ldots\ldots (15)$$

$$E\,y = \int_o^x \int_o^x \frac{M}{I}\,dx\,dx \quad \ldots\ldots (16)$$

and it is seen at once that:

$$\frac{E}{W_n}\,y_{4n-3} = \int_o^{l_n} \int_o^{l_n} \frac{l_n - x}{l_n}\,dx\,dx \quad \ldots\ldots (17)$$

* A "graded" spring is one whose leaves are not all of the same thickness.

$$\frac{E}{W_n} y_{4n-2} = \int_0^{l_{n-1}} \int_0^{l_{n-1}} \frac{l_n - x}{I_n} dx\, dx \quad \ldots\ldots (18)$$

$$\frac{E}{W_n} y_{4n-1} = \int_0^{l_n} \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx\, dx \quad \ldots\ldots (19)$$

and also:

$$y_{4n} = y_{4n-1} + (l_{n+1} - l_n) \frac{dy}{dx}_{l_n} \quad \ldots\ldots (20)$$

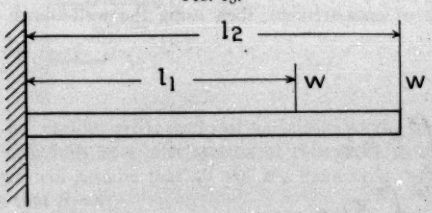
or:

$$\frac{E}{W_n} y_{4n} = \int_0^{l_n} \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx\, dx + (l_{n+1} - l_n) \int_0^{l_n} \frac{l_n - x}{I_{n+1}} dx. \quad \ldots\ldots (21)$$

No constants are added to the integrals, since both $\frac{dy}{dx}$ and y vanish together with x.

These general relations, as here given, are of course in a somewhat intangible form for practical use; they will be reduced to definite formulæ for particular cases later on, but before doing so, we will prove a very important theorem, which shows that $A_{4n-2} = A_{4n-4}$, so that when A_{4n-4} has been calculated, A_{4n-2} may at once be written down as the same, thus saving twenty-five per cent. of the preliminary work.

FIG. 15.



Theorem: With any cantilever (see Fig. 15) the deflection at l_1 due to a load W at l_2 is equal to the deflection at l_2 due to a load W at l_1.

In general, if the load W is distant l from the point of encastrèment, the bending moment M is $W(l - x)$, and if we put $\frac{1}{I} = f(x)$, where $f(x)$ is any function of x, and apply the standard

equation (14), we at once obtain:

$$\frac{E}{W}\frac{d^2y}{dx^2} = l f(x) - x f(x)$$

$$\frac{E}{W}\frac{dy}{dx} = l \int f(x)\,dx - \int x f(x)\,dx$$

say

$$= l F(x) - G(x)$$

$$\frac{E}{W} y = l \int F(x)\,dx - \int G(x)\,dx$$

Now integrating the first term by parts, using unity as one factor, and writing $H(x)$ for the second term, there results:

$$\frac{E}{W} y = l \left\{ x F(x) - \int x \frac{d}{dx} F(x)\,dx \right\} - H(x)$$

$$= l \left\{ x F(x) - \int x f(x)\,dx \right\} - H(x)$$

$$= l \left\{ x F(x) - G(x) \right\} - H(x)$$

Making use of these relations, the deflection at l_1 due to W at l_2 is:

$$l_1 \left\{ l_1 F(l_1) - G(l_1) \right\} - H(l_1)$$

The deflection at l_2 due to W at l_1 is:

$$l_1 \left\{ l_1 F(l_1) - G(l_1) \right\} - H(l_1) + (l_2 - l_1) \left\{ l_1 F(l_1) - G(l_1) \right\}$$

$$= l_2 \left\{ l_1 F(l_1) - G(l_1) \right\} - H(l_1)$$

the same as before; this then proves the theorem.

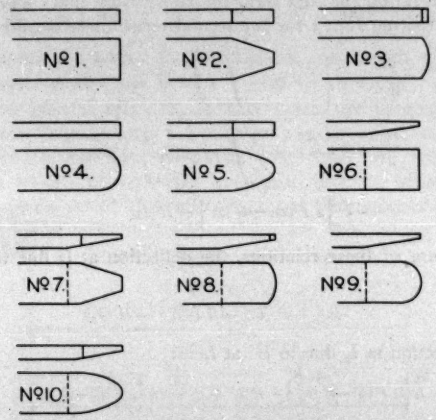
We may now proceed with the evaluation of the fundamental constants, or A's, for plates with various types of ends or points. The most usual types of points are shown by Fig. 16, and the common names of them are as follows:

No. 1. Square, or plain;
No. 2. Trimmed, or trapezoidal (trap');
No. 3. Round;
No. 4. Circular;

No. 5. Parabolic, oval, or egg-shaped;
No. 6. Square-tapered, or plain-tapered;
No. 7. Trimmed-tapered, or trapezoidal-tapered;
No. 8. Round-tapered;
No. 9. Circular-tapered;
No. 10. Parabolic-tapered, oval-tapered, or egg-shape-tapered.

There are various other shapes of points in use but those shown in the Fig. 16 are the most common and also the most important. In many cases, the leaves are finished with a slight

FIG. 16.



bevelling of the ends, but this is of no importance from the present point of view as it is merely a matter of appearance.

Now proceeding to the calculations the first and simplest case is of course that of:

No. 1 or Square Leaf Point.

For this point the leaves are simply cut off "square" and there is no tapering either in the width or in the thickness.

For this case, which is simply that of a simple cantilever of uniform section and loaded at the end, if l is the length and y

the deflection at the distance x from the point of encastrèment, we have:

$$EI\frac{d^2y}{dx^2} = W(l-x) \quad \ldots\ldots(22)$$

$$EI\frac{dy}{dx} = W\left(lx - \frac{x^2}{2}\right) \quad \ldots\ldots(23)$$

$$EI\ y = W\left(\frac{dx^2}{2} - \frac{x^3}{6}\right) \quad \ldots\ldots(24)$$

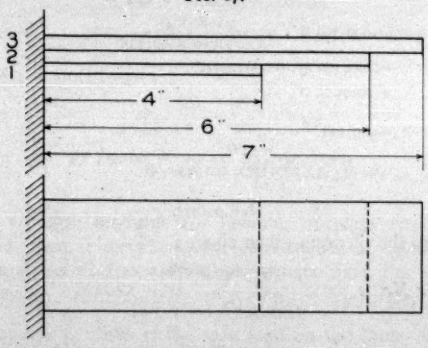
and at the end, when $x = l$, we have

$$EI\frac{dy}{dx} = \frac{Wl^2}{2} \quad \ldots\ldots(23a)$$

$$EI\ y = \frac{Wl^3}{3} \quad \ldots\ldots(24a)$$

and these relations are all that are necessary in order to make the calculations for a spring with the No. 1 or square points to the leaves.

FIG. 17.



Considering the somewhat extensive abstract work of the preceding, it may now be well to give a practical example, showing the application of the foregoing to a particular concrete case. The spring for which the calculations will be worked out is shown in Fig. 17, for which we will take plate No. 1 as $2'' \times 3/16''$ with $I_1 = .001099$ and $Z_1 = .01172$; plate No. 2 as $2'' \times 7/32''$ with $I_2 = .001745$ and $Z_2 = .01595$; and plate No. 3 as $2'' \times 1/4''$ with $I_3 = .002604$ and $Z_3 = .02084$. E will be taken as $28 \times 10.^6$

Now, in order to calculate the A's we have:

For Plate No. 1.

$$l_1 = 4,\ I_1 = .001099,$$

and

$$y_1 = \frac{W_1 \times 4^3}{3 \times 28 \times 10^6 \times .001099} = .0006933\ W_1$$

or:

$$A_1 = .0006933.$$

A_2 is zero always, as mentioned previously, being only introduced for the sake of symmetry of the mathematical expressions.

For Plate No. 2.

$$l_1 = 4,\ l_2 = 6,\ I_2 = .001745,$$

and

$$y_2 = \frac{W_1 \times 4^3}{3 \times 28 \times 10^6 \times .001745} = .0004366\ W_1$$

or

$$A_2 = .0004366$$

$$y_4 = y_2 + (l_2 - l_1)\left(\frac{dy}{dx}\right)_1$$

$$= .0004366\ W_1 + \frac{2 \times W_1 \times 4^2}{2 \times 28 \times 10^6 \times .001745}$$

$$= .0004366\ W_1 + .0003275 W_1$$

$$= .0007641\ W_1$$

or

$$A_4 = .0007641.$$

$$y_3 = \frac{W_2 \times 6^3}{3 \times 28 \times 10^6 \times .001745} = .001473\ W_2$$

or

$$A_3 = .001473.$$

From the theorem given above:

$$A_4 = A_4 = .0007641.$$

For Plate No. 3.

$$l_2 = 6,\ l_3 = 7,\ I_3 = .002604,$$

and

$$y_7 = \frac{W_2 \times 6^3}{3 \times 28 \times 10^6 \times .002604} = .0009875\ W_2$$

or

$$A_7 = .0009875.$$

$$y_8 = y_7 + (l_3 - l_2)\left(\frac{dy}{dx}\right)_2$$

$$= .0009875\ W_2 + \frac{W_2 \times 6^2}{2 \times 28 \times 10^6 \times .002604}$$

$$= .0009875\ W_2 + .0002469\ W_2$$

$$= .001234\ W_2$$

or

$$A_8 = .001234$$

$$y_8 = \frac{W_3 \times 7^3}{3 \times 28 \times 10^6 \times .002604} = .001568\, W_3$$

or

$$A_9 = .001568$$

From the theorem:

$$A_{10} = A_8 = .001234.$$

Having now determined the values of all the A's, the B's and C's may readily be found, thus:

$$B_1 = A_1 = .0006933$$

$$C_1 = \frac{A_8}{B_1 + A_1} = \frac{.0007641}{.0006933 + .0004366} = .6763$$

$$B_2 = A_8 - A_4 C_1 = .001473 - .0007641 \times .6763 = .0009562$$

$$C_2 = \frac{A_{10}}{B_2 + A} = \frac{.001234}{.0009562 + .0009875} = .6349$$

$$B_3 = A_9 - A_8 C_2 = .001568 - .001234 \times .6349 = .0007845$$

It may be also noted that:

$$W_2 = \frac{W_1}{C_1} = \frac{W_1}{.6763} = 1.479\, W_1$$

and

$$W_3 = \frac{W_2}{C_2} = \frac{1.479 W_1}{.6349} = 2.330\, W_1$$

The strength modulus for bending of plate No. 1 being $Z = .01172$, then if we allow, for convenience of calculation, a maximum stress of 100,000 lbs. per square inch, the safe load W_1 will be $\frac{100000 \times .01172}{4} = 293$ lbs. $W_2 = 293 \times 1.479 =$ 433 lbs. and W_3, which is the safe load on the three-leaf cantilever spring, will be $293 \times 2.330 = 683$ lbs. Also, as the deflection is B_3 inches per lb. of W_3, the stiffness of the spring is $\frac{1}{B_3} =$ 1275 lbs. load per inch deflection.

The bending moment in plate No. 2, directly over the tip of plate No. 1, is $433 \times 2 = 866$ in. lbs. and as $Z_2 = .01595$ the stress is $866/.01595 = 54{,}290$ lbs. per sq. in. At the centre the bending moment is $433 \times 6 - 293 \times 4 = 1426$ in. lbs. with a stress of 89,400 lbs. per sq. in.

For plate No. 3, the bending moment directly over the tip of plate No. 2 is $683 \times 1 = 683$ in. lbs. with a stress of 32.770 lbs. per sq. in. and at the centre the bending moment is $683 \times 7 - 433 \times 6 = 2183$ in. lbs. with a stress of 104,750 lbs. per sq. in.

This last result is interesting, as it shows a slightly higher stress in the master leaf than in the short one; as previously mentioned, this is not of common occurrence and cannot occur with a non-graded non-tapered spring, but it may and sometimes does occur with graded and tapered springs. The new theory thus accounts for the observed facts that with some types of springs the short leaf nearly always breaks first, while with other springs —as in the particular case just given—it is the master leaf which is usually the first to fracture. There are, of course, intermediate conditions, when one of the intermediate leaves is most apt to break, but these are few in comparison with the cases of fracture of either the short or the master leaf.

The square-point leaf is in such general use, especially for the heavier grades of springs, that it is desirable to simplify, as much as possible, the calculations for the reactions and deflections of this style of spring. This can be done to a considerable extent in the following manner:

Referring back to the fundamental equation (7), it will be found that this can be rewritten as follows:

$$\frac{2\,W_n\left(\frac{I_{n+1}}{I_n}+1\right)-W_{n-1}\frac{I_{n+1}}{I_n}\left\{\left(\frac{l_{n-1}}{l_n}\right)^3\left(3\,\frac{l_n}{l_{n-1}}-1\right)\right\}}{3\,\frac{l_{n+1}}{l_n}-1} \qquad (25)$$

and if we write

$$P_n \text{ for } \frac{I_{n+1}}{I_n},\ Q_n \text{ for } \frac{l_{n+1}}{l_n},\text{ and } R_{n-1} \text{ for } \frac{3Q_{n-1}-1}{Q_{n-1}^3}$$

we obtain:

$$W_{n+1} = \frac{2\,W_n\,(P_n+1) - W_{n-1}\,P_n\,R_{n-1}}{3\,Q_n - 1} \qquad (26)$$

which is a reasonably simple formula for practical manipulation.

In order to facilitate the practical use of this equation (26) we have calculated the values of the function of Q_{n-1} denoted by R_{n-1}, and these are given in Table No. VII.

Table VII.

Q_{n-1}	R_{n-1}	Dif.	Q_{n-1}	R_{n-1}	Dif.
1.00	2.0000	297	1.57	.9587	105
1.01	1.9703	291	1.58	.9482	103
1.02	1.9412	285	1.59	.9379	102
1.03	1.9127	280	1.60	.9277	100
1.04	1.8847	274	1.61	.9177	98
1.05	1.8573	269	1.62	.9079	97
1.06	1.8304	264	1.63	.8982	95
1.07	1.8040	258	1.64	.8887	94
1.08	1.7782	253	1.65	.8793	92
1.09	1.7529	249	1.66	.8701	91
1.10	1.7280	243	1.67	.8610	90
1.11	1.7037	239	1.68	.8520	88
1.12	1.6798	234	1.69	.8432	87
1.13	1.6564	230	1.70	.8345	85
1.14	1.6334	225	1.71	.8260	85
1.15	1.6109	221	1.72	.8175	83
1.16	1.5888	216	1.73	.8092	81
1.17	1.5672	213	1.74	.8011	81
1.18	1.5459	208	1.75	.7930	79
1.19	1.5251	205	1.76	.7851	79
1.20	1.5046	200	1.77	.7772	77
1.21	1.4846	197	1.78	.7695	76
1.22	1.4649	193	1.79	.7619	74
1.23	1.4456	190	1.80	.7545	74
1.24	1.4266	186	1.81	.7471	73
1.25	1.4080	183	1.82	.7398	72
1.26	1.3897	179	1.83	.7326	70
1.27	1.3718	176	1.84	.7256	70
1.28	1.3542	173	1.85	.7186	69
1.29	1.3369	169	1.86	.7117	67
1.30	1.3200	167	1.87	.7050	67
1.31	1.3033	163	1.88	.6983	66
1.32	1.2870	161	1.89	.6917	65
1.33	1.2709	158	1.90	.6852	64
1.34	1.2551	155	1.91	.6788	63
1.35	1.2396	152	1.92	.6725	63
1.36	1.2244	149	1.93	.6662	61
1.37	1.2095	147	1.94	.6601	60
1.38	1.1948	144	1.95	.6541	60
1.39	1.1804	142	1.96	.6481	59
1.40	1.1662	140	1.97	.6422	58
1.41	1.1522	136	1.98	.6364	57
1.42	1.1386	135	1.99	.6307	57
1.43	1.1251	132	2.00	.6250	111
1.44	1.1119	130	2.02	.6139	108
1.45	1.0989	128	2.04	.6031	105
1.46	1.0861	126	2.06	.5926	103
1.47	1.0735	124	2.08	.5823	100
1.48	1.0611	121	2.10	.5723	98
1.49	1.0490	120	2.12	.5625	95
1.50	1.0370	117	2.14	.5530	94
1.51	1.0253	116	2.16	.5438	91
1.52	1.0137	113	2.18	.5347	88
1.53	1.0024	112	2.20	.5259	86
1.54	.9912	110	2.22	.5173	84
1.55	.9802	109	2.24	.5089	82
1.56	.9693	106	2.26	.5007	80

TABLE VII.—*Continued.*

Q_{n-1}	R_{n-1}	Dif.	Q_{n-1}	R_{n-1}	Dif.
2.28	.4927	78	2.66	.3709	52
2.30	.4849	76	2.68	.3657	50
2.32	.4773	75	2.70	.3607	49
2.34	.4698	72	2.72	.3558	48
2.36	.4626	72	2.74	.3510	47
2.38	.4554	69	2.76	.3463	47
2.40	.4485	68	2.78	.3416	45
2.42	.4417	66	2.80	.3371	44
2.44	.4351	65	2.82	.3327	44
2.46	.4286	64	2.84	.3283	43
2.48	.4222	62	2.86	.3240	42
2.50	.4160	61	2.88	.3198	41
2.52	.4099	59	2.90	.3157	40
2.54	.4040	58	2.92	.3117	40
2.56	.3982	57	2.94	.3077	39
2.58	.3925	56	2.96	.3038	38
2.60	.3869	55	2.98	.3000	37
2.62	.3814	53	3.00	.2963	
2.64	.3761	52			

In order to show the utility of this equation and table, we will now work out the same spring (Fig. 17) that we have solved above, by this method.

First find the values of the P's and Q's, thus:

$$P_1 = .001754/.001099 = 1.588$$
$$P_2 = .002604/.001745 = 1.492$$
$$Q_1 = 6/4 = 1.500$$
$$Q_2 = 7/6 = 1.167$$

R_1 is to be taken from Table VII, opposite the value of Q_1, or 1.500, where we find $R_1 = 1.0370$. For R_2, corresponding to Q_2, we find 1.5888 as the tabular value corresponding to 1.16, with a first difference of 216 and $216 \times .7 = 151$ which must be *subtracted* from the 1.5888 since R decreases as Q increases, thus giving 1.5737 as the value of R_2.

Next inserting these values in equation (26) and putting $W_1 = 1$ we have, since $W_0 = 0$:

$$W_2 = \frac{2\,(P_1+1)}{3Q_1 - 1} = \frac{2\,(1.588 + 1)}{3 \times 1.5 - 1} = 1.479$$

$$W_3 = \frac{2\,W_2\,(P_2 + 1) - W_1\,P_2\,R_1}{3Q_2 - 1}$$

$$= \frac{2 \times 1.478\,(1.492 + 1) - 1.492 \times 1.037}{3 \times 1.167 - 1} = 2.327$$

these values being almost exactly the same as before—if more figures were taken they would be exactly the same, and in any case the differences are practically negligible.

The same table (VII) can be used for simplifying the deflection calculations, for the deflection coefficient B_n may be written in the form:

$$B_n = \frac{K_n P_n}{6 E I_n} \quad \ldots\ldots (27)$$

where:

$$K_n = 2 - \frac{W_{n-1}}{W_n} R_{n-1} \quad \ldots\ldots (28)$$

To apply this to the above case, we have $n = 3$ for the three-plate spring,

$$I_3 = .002604,\ l_3 = 7,\ W_2 = 1.479,\ W_3 = 2.327,$$

$$K_3 = 2 - \frac{W_2 R_2}{W_3} = 2 - \frac{1.479 \times 1.5737}{2.327} = .9995$$

and

$$B_3 = \frac{.9995 \times 7^3}{6 \times 28 \times 10^6 \times .002604} = .0007837$$

which is sensibly the same as obtained before. It will easily be seen that this method of calculation greatly reduces the labor of computation in cases where square-point leaves are concerned. For most practical cases where the leaf ends are "trap" points the present formulæ may be used—we shall see that this is the case in the later portion of the present paper.

(To be concluded.)

Jerusalem Has New Water-supply. ANON. (*Engineering News-Record*, vol. 81, No. 20, p. 890, November 14, 1918. Through the *London Surveyor*.)—Following closely upon the occupation of Jerusalem by the British, investigations for a new water-supply were begun by the Royal Engineers. Four days later a scheme was outlined. This was on February 14th but shortage of transportation facilities and bad weather put off the beginning of construction until about the second week in April. On June 18th water was being delivered. The supply is pumped from springs to the city. Many miles of pipe have been laid, and the supply is being delivered directly to hospitals, to "stand-pipes in every quarter of the city" and also to cisterns, the latter on condition that the cisterns be cleaned out to the satisfaction of the water authorities before they are filled. The daily yield of the springs is about 400,000 U. S. gallons. The water consumption of the city is said to be about ten times what it was formerly. It is reported that the "beneficial effects upon the health of the city has been instant and widespread."

Scientific Management versus Its Practical Adaptation. G. S. ANDRASSY (*Machinery*, vol. 25, No. 2, p. 132, October, 1918).—True scientific management is practically nothing but discernment of the obvious: common sense backed by enough education and training to develop ideas into practical results. A reasonably good engineer or accountant is peculiarly fitted by training to succeed in efficiency work, though men of other callings have been very successful in it. The whole theory and profession of scientific management, however, is becoming a subject for jest through the efforts of two types of individuals. The first is the half-trained, self-assertive person with a superabundance of theory, who fails to discern the difference between one business and another, and would apply the same methods to all. He lacks the practical experience necessary to instruct others and is fundamentally unfitted for the work and unable to analyze the small details that make up any action in life. The second is the person with the scientific mind. He has a thirst for knowledge and is willing to spend two dollars gathering details about how a dollar's worth of profit ought to be made. He compiles tables and files any information about all kinds and conditions of business and operations, but in many cases neither details, tables nor information have any practical value, and this management expense goes to the overhead.

Scientific management is overburdened with system and form. The basic facts are good, and nearly any business can be improved by employing a competent man who has nothing else to think or worry about but improvement. A company employing such a man usually expects too much, and, to get the worth of its money, wants to see the outward indications of the changes and improvements looked for. The average business employs people of ordinary intelligence, and practical and profitable change is more a matter of gathering up the loose ends and organizing a system of execution than it is radically changing present methods. If the man called in will stop systematizing and information-gathering when he knows he ought to stop, the business will benefit; but if he feels obliged to continue because more is expected of him, or because he wants to know—because he is half-inventor and wants to see some way of his supersede some other way—or because he merely desires to pose as the expert—then the business will suffer. It is sometimes the quiet, unobtrustive, meek sort of fellows who produce the best results, but it is usually the loud talkers and the installers of much system that get the salary. As money is what most people are after, there are more of the second class of efficiency men than there are of the first.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.

BY

JOSHUA J. SKINNER, Ph.D.

Effect of Aldehydes With and Without Fertilizers on Dunkirk Clay Loam.

THE RESULTS OBTAINED.

An experiment to test the action of aldehydes on a third soil in the field was conducted on the Dunkirk clay loam on the experimental farm of the Cornell Experiment Station at Ithaca, N. Y., in 1916.

The soil on which the experiment is laid out is the silty phase of the Dunkirk clay loam. It is stiff and rather compact and runs together, making it difficult to cultivate. The field produces average crops for the section, yet it is a less productive soil than the Hagerstown loam at State College, Pa. Lime benefits the soil for clover, but not especially for grass. When examined in the laboratory the soil was found to be very acid, and its oxidizing power was much less than either the Hagerstown loam or the Arlington soil on which the aldehyde experiments were made.

As in the two former field experiments, cowpeas were grown. The climate is rather cold and the season too short in this section of New York for cowpeas, but, inasmuch as the other field experiments were made with cowpeas, it was desired to grow the same crop in this soil.

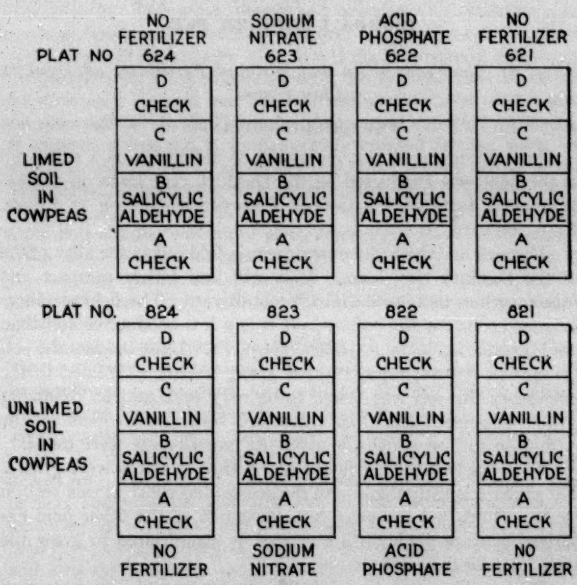
The vanillin, salicylic aldehyde, fertilizers, and lime were used in the same amounts as in the former experiments, and the aldehydes and fertilizers were applied in three portions as before. The arrangement of the plots was somewhat different from that of the other experiments. These plots were 10 feet by 6.8 feet—one six-hundred-and-fortieth of an acre—the same size as the Arlington plots. The plan of the experiment and arrangement of the plots is shown in Fig. 68. Three rows of peas were planted in

* Concluded from page 584, Vol. 186, November, 1918.

each plot, the rows being 2 feet from the edge of the plot and 4 feet apart. The peas were planted May 29, 1916.

The cowpeas made a poor growth on the entire set of plots: the best did not reach a height of 12 inches. On the unlimed soil the plants on the untreated plots grew to a height of about 8

FIG. 68.



Plan of the aldehyde fertilizer experiment on the Dunkirk clay loam at the Cornell Experiment Station.

inches. The effect of the vanillin and salicylic aldehyde was very marked. Germination was affected on the vanillin and salicylic aldehyde plots of the unfertilized, unlimed section; that is, plots No. 621 B and C and No. 624 B and C. A number of these plants died when an inch or two high, and those that survived made a scant growth. The plants on the vanillin and salicylic aldehyde plots, which were fertilized with sodium nitrate and acid

phosphate, grew much better, but in their early stage of growth they were not as good as the plants on the untreated soil.

The aldehydes were not so harmful on the limed soil, yet it was perceptible that the plants were making a slower growth than in the limed soil to which no aldehydes were added. Where the limed soil was fertilized with sodium nitrate and acid phosphate the aldehydes did not appear to be checking growth in the early stage of the plants.

The crop was harvested on September 6. The plants had made their full growth and were in the fruiting stage at this time. The results are given in Table XXI.

TABLE XXI.

Effect of Vanillin and Salicylic Aldehyde on Cowpeas in the Field on Dunkirk Clay Loam, and the Action of Fertilizers in Modifying Their Effects (Weights Given in Pounds Per Plot).

Plot No.	Treatment	Unlimed soil				Plot No.	Limed soil			
		Green weight		Dry weight			Green weight		Dry weight	
		Hay	Relative	Hay	Relative		Hay	Relative	Hay	Relative
	No-fertilizer section:									
821 A	Check	10.7	100	3.2	100	621 A	10.9	100	2.5	100
821 D	Check	10.2		2.6		621 D	9.6		2.7	
821 B	Salicylic aldehyde	1.0	9	0.2	7	621 B	7.4	72	1.7	65
821 C	Vanillin	1.9	18	0.4	14	621 C	8.4	82	2.4	92
	Acid phosphate section:									
822 A	Check	7.1	100	1.8	100	622 A	8.6	100	2.0	100
822 D	Check	6.4		1.5		622 D	11.2		2.6	
822 B	Salicylic aldehyde	5.5	81	1.4	85	622 B	8.6	86	2.0	86
822 C	Vanillin	6.1	90	1.4	85	622 C	8.1	81	2.0	86
	Sodium nitrate section:									
823 A	Check	7.9	100	2.1	100	623 A	10.5	100	2.4	100
823 D	Check	8.1		1.9		623 D	7.6		1.7	
823 B	Salicylic aldehyde	6.5	81	1.6	80	623 B	9.7	107	2.3	112
823 C	Vanillin	6.2	77	1.6	80	623 C	9.1	100	2.6	127
	No-fertilizer section:									
824 A	Check	8.3	100	2.3	100	624 A	8.0	100	1.9	100
824 D	Check	6.6		1.6		624 D	9.1		2.3	
824 B	Salicylic aldehyde	1.8	24	0.4	22	624 B	7.9	92	1.8	86
824 C	Vanillin	2.0	27	0.5	27	624 C	7.1	85	1.7	81

Considering first the unlimed soil, it is seen in the table that the yield from the vanillin and salicylic aldehyde plots of the two unfertilized sections (Plots 821 and 824) is very small as compared with their checks. In the acid phosphate section (Plot 822) salicylic aldehyde reduced green weight from 100, as an average of the two checks, to 81, a reduction of 19 per cent. The vanillin

reduced growth from 100 to 90, a reduction of 10 per cent. In dry weight both substances reduced growth from 100 to 85, 15 per cent. In the sodium nitrate section (Plot 823) both compounds reduced the dry weight from 100 to 80, a reduction of 20 per cent. Neither aldehyde had nearly so bad an effect on the fertilized soil as they did on the untreated soil. When the green weight is used as a criterion, acid phosphate had more effect in lessening the harmfulness of vanillin than it did of salicylic aldehyde, which is not altogether in harmony with former results on other soils. Sodium nitrate also lessened the harmfulness of both compounds in this soil, while in other soils sodium nitrate overcame the effect of vanillin, but did not have so marked an effect on salicylic aldehyde.

On the unfertilized limed soil (Plots 621 and 624) both compounds checked growth considerably, but the harmfulness was not so great as on the unlimed soil. This was true to a somewhat less extent on the limed soil to which acid phosphate was added (Plot 622), but on the limed soil to which sodium nitrate was applied (Plot 623) there was no reduction in growth from either vanillin or salicylic aldehyde.

It is apparent from the results that both vanillin and salicylic aldehyde are very harmful in this soil, even more so than in the Arlington soil. The fact that the crop grown, cowpeas, was not suitable for the New York climate may be a factor in the degree of damage which the crop received, yet the results given show undoubtedly that the aldehydes are harmful in this soil, and it will be pointed out later that the aldehydes remained in the soil throughout the growing season. The lime and fertilizer helped the conditions toward betterment of growth, but the aldehydes had their effects even under these conditions.

Effect of Vanillin and Salicylic Aldehyde on the Oxidation of the Soil.

It was pointed out before that the Dunkirk clay loam has a poor oxidizing power. The Arlington soil had about three times the oxidizing power and the Hagerstown loam about five times that of the Dunkirk soil. The oxidation power of the soil in the plots made on samples taken near the end of the growing season is given in Table XXII. The oxidation of the untreated soil is taken as 100.

TABLE XXII.

Effect of Aldehydes and Fertilizers on the Oxidation Power of Dunkirk Silty Clay Loam.

Treatment	Plot No.	Relative oxidation unlimed soil	Plot No.	Relative oxidation limed soil
Untreated plot	821 A	100		
Vanillin	821 C	51	621 C	97
Vanillin	824 C	82	624 C	125
Vanillin, acid phosphate	822 C	250	622 C	125
Vanillin, sodium nitrate	823 C	230	623 C	125
Salicylic aldehyde	821 B	90	621 B	105
Salicylic aldehyde	824 B	84	624 B	95
Salicylic aldehyde, acid phosphate	822 B	127	622 B	120
Salicylic aldehyde, sodium nitrate	823 B	125	623 B	122

The addition of vanillin and salicylic aldehyde to this soil, already weak in its oxidizing power, still further reduced this function of the soil. The vanillin in one plot on the unlimed, unfertilized soil reduced the oxidation from 100 for the untreated soil to 51, and in the second plot from 100 to 82. The salicylic aldehyde in one plot reduced the oxidation from 100 for the untreated plot to 90, and in the other from 100 to 84. The plots to which the aldehydes were added together with sodium nitrate or acid phosphate had a stronger oxidizing power than the untreated soil, showing that the fertilizers had stimulated oxidation even in the presence of the aldehydes which tend to check this function in a weak soil. Liming the soil also produced an effect on its oxidizing power, but the results do not show clearly that it has aided materially, as did the fertilizers. The action of fertilizers and lime in overcoming the retarding effect of aldehydes in soil oxidation is again in harmony with the effect of fertilizers and lime in ameliorating their harmfulness in growth.

Examination of Soils for Aldehydes at the End of the Growing Season.

Samples of soil were taken from each plot at the time the crop was harvested in order to determine whether or not the aldehyde had remained in the soil as such throughout the growing season. Thirty pounds of soil from each plot was subjected to the method for the isolation of aldehydes. The odor of vanillin could be detected in the soil all during the season, and it was faintly perceptible even at the time the crop was harvested.

Aldehydes were found to be present in each of the unfertilized plots (Nos. 821 C and 824 C) on the unlimed soil to which vanillin had been added. It was found also in both of the unfertilized plots on the unlimed soil to which salicylic aldehyde was added (Nos. 821 B and 824 B).

Aldehydes were also found in the plot fertilized with sodium nitrate to which vanillin was added (No. 823 C), but none was found in the vanillin plot (No. 822 C) fertilized with acid phosphate.

The salicylic aldehyde plot (No. 823 B) fertilized with sodium nitrate did not show the presence of aldehyde, while the salicylic aldehyde plot fertilized with acid phosphate (No. 822 B) was found to contain the aldehyde material.

Of the limed soils only two plots were found to contain aldehyde material. These were plots Nos. 621 B and 624 B, the unfertilized plots to which salicylic aldehyde had been added. No aldehydes could be isolated from any of the other plots.

The results of the analysis of the soil show that the aldehydes remained in most of the unlimed plots throughout the growing season. Out of the eight plots on the unlimed soil to which vanillin and salicylic aldehyde were added six were found to contain the aldehydes, and in two no aldehydes could be isolated. In each of the unfertilized plots to which vanillin and salicylic aldehyde were added, the plots which made the poorest growth, the aldehydes were found to remain in the soil.

The experiment on the Dunkirk clay loam again demonstrates that if the aldehydes are not destroyed in the soil they will have detrimental effect on the crop growing therein. Davidson (16), who worked with the Dunkirk clay loam in pots holding three gallons of soil, found that vanillin used in amounts of 1000 parts per million reduced the production of grain and straw of wheat 10.3 per cent. on unfertilized soil. With 500 and 100 parts per million there was no decreased growth. On limed soil 1000 parts per million reduced growth 21 per cent., and 500 parts per million 14 per cent. It is rather surprising that the vanillin should be more harmful in his experiment on limed soil, as in all controlled experiments with vanillin it has been found to be changed in a limed soil. The vanillin was not as harmful in his tests when the soil was fertilized with phosphoric acid. This is somewhat in harmony with the field experiments reported in this paper, where

it is shown that the vanillin was not as harmful when fertilized with acid phosphate, and it is interesting also to note that the aldehydes had disappeared from this plot when examined at the end of the crop season. It is unfortunate that Davidson did not determine this point in his work. The irregularities in growth under the different fertilization treatments might have been explained had he determined whether the added vanillin remained in his differently treated cultures or whether it was destroyed. On account of the wide variations in the chemical and biological nature of different soils, or of the same soil when kept under different conditions, it seems unsafe to draw conclusions as to the behavior of added organic substances in soils without determining whether or not the added substance remains as such in the soil.

From the results of the field experiments it is seen that the added salicylic aldehyde and vanillin are harmful in this soil, and that the added aldehydes remained in the soils at least throughout the growing season. The soil is shown to have a low oxidizing power, which is lessened by the additions of aldehydes and is increased by the application of fertilizers.

Summary of the Results of Field Experiments With Aldehydes.

Field experiments with salicylic aldehyde and vanillin were made on three soils, each being of a different geological origin, having different chemical and biological characteristics, different crop-producing powers, and situated in widely different geographical locations.

Both aldehydes persisted and were harmful in two of the soils, and were destroyed and consequently were not harmful in the third.

The two soils in which the aldehydes persisted are acid soils, having weak oxidizing activities and lower crop-producing powers than the soil in which the aldehydes disappeared. The soil on which the aldehydes were destroyed and produced no harmful effect on crops is a limestone soil, with strong biological activities and good crop-producing powers.

The aldehydes did not long remain as such in the two soils when limed, and their harmfulness in the limed soil was greatly lessened. Fertilizers have an effect on the physiological action

of both aldehydes. The effects of salicylic aldehyde were partially overcome by acid phosphate and that of vanillin by sodium nitrate, which is in harmony with the action of these salts on the aldehydes in nutrient-culture solutions.

THE ELIMINATION OF ALDEHYDES FROM FIELD SOILS BY SOIL TREATMENT.

The experiments thus far presented deal with the effects of added aldehyde in soils. Evidence has been secured to show that with a rational fertilizer treatment the added aldehydes lose their harmfulness and are even destroyed by biological activities induced by fertilizer application. The next step in the investigation is a study of a soil in which salicylic aldehyde was formed by Nature therein and has remained or continued to be formed for at least four years. The investigation of this soil has substantiated the results thus far secured in the experiments where the aldehydes were added, and has made it possible to suggest treatments to remedy the unfertility of a soil, where this unfertility is due to the presence of harmful aldehydes.

Experiments on Mount Vernon Garden Soils.

In an investigation of the soils of the Mount Vernon estate, Virginia, the historic home of George Washington, a study was made of the organic constituents of the soils of the flower gardens. When subjected to the methods for isolating organic substances from soils, devised in the Laboratory of Soil Fertility Investigations, saccharic acid, acrylic acid, mannite, and salicylic aldehyde were found. Of these, compound salicylic aldehyde has proved the most interesting, and, as it has been found to have considerable influence on plants, this study is concerned with it principally.

The soil of the flower garden is a brown mellow loam containing enough sand and vegetable matter to effect an excellent structural condition. At a depth of about 15 inches the surface soil passes into a reddish-brown to yellowish-brown clay loam. This subsoil in turn grades into a compact red clay, faintly mottled in places with grayish colors, at a depth of approximately 24 inches. This layer of material resembles a hard-pan formation. This compact condition undoubtedly affects the movement of

moisture and air. The examination of the soil in the laboratory showed that the surface soil was acid and the subsoil decidedly so.

Box hedges, roses, and violets have grown in the gardens for over a century; in fact, the original plan of the garden as inaugurated and kept by General Washington himself is still preserved, and the same kind of vegetation is still grown. When the investigation was undertaken in 1912 the box hedges and roses were doing poorly. The hedges were growing unsatisfactorily, and the roses were making a scant growth. There was danger of their complete failure.

From the laboratory examination made in 1912 it was first found that the garden soils contained the harmful salicylic aldehyde. The salicylic aldehyde probably formed in this soil from the decay of the high nitrogenous manure applied bountifully year after year. The decay of the large number of roots from the box hedges, which have grown in the soil since the days of Washington, may also have been a contributing factor.

As a remedy for the unsatisfactory soil conditions, a good system of underdrainage was installed. Lime was added to correct the acid condition of the soil, and a basic phosphate fertilizer was applied.

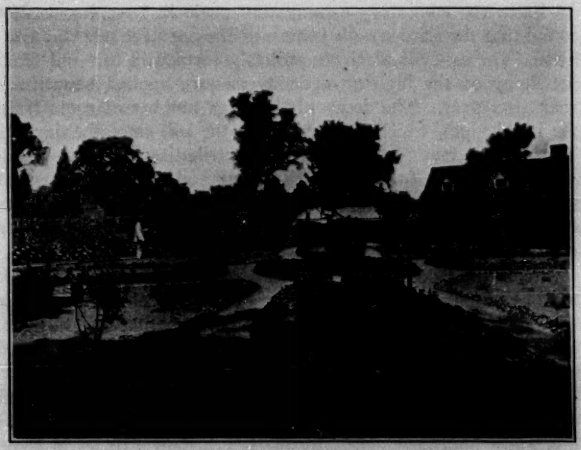
From the laboratory, greenhouse, and field results secured it has been found that the bad effects of salicylic aldehyde in soils were remedied by lime and acid phosphate, and that the aldehyde, when added to limed soils, was destroyed. As a result of this experiment the above treatments were suggested.

For several years following the treatment with lime and phosphate fertilizer the general condition of most of the garden was much improved, especially the box hedges. Roses in some parts of the garden, however, still made a very poor and unsatisfactory growth, while in other beds they did well. An examination of the poor rose bed in October, 1916, showed that the subsoil was stiff and gummy, while a nearby bed which grew good roses had a friable subsoil. A laboratory examination of the soil from the two beds showed them both to be alkaline, and both contained the same amount of soluble fertilizing salts. The poor soil at this time was found to contain aldehydes, while the good soil did not.

A greenhouse experiment made on the soil at this time also showed it to contain some soluble material of a harmful nature

(69). Cowpeas were grown in the soil in greenhouse bench beds. In one bed porous tubes containing carbon black were buried. The carbon black is a very good absorber, and removes any soluble organic substance from the soil moisture as it moves in and out the tubes. The cowpeas were much improved in the bed containing the carbon tubes. The untreated bed produced 412 grammes of green crop, and the bed containing the carbon 640 grammes, an appreciable increase in growth.

FIG. 69.



Showing the poor condition of the rose bushes in the Mount Vernon garden, a soil containing salicylic aldehyde, and the soil aldehyde experiment in the foreground.

It was three years ago that this soil was first found to contain aldehydes, and it is interesting to note that conditions were such that it could continue to be formed and remain in the soil over a period of years.

An experiment was planned and made in 1916 on the poor rose bed, which still contained aldehyde, in order to further study means of improving a soil which naturally contained aldehyde. The outline and results of the experiment are given below.

The bed was divided into four plots, each plot 4 feet by 6

feet. One bed was left untreated; to another lime was added at the rate of 1½ tons per acre; to the third acid phosphate was added at the rate of 800 pounds per acre, and to the fourth both lime and acid phosphate were applied. The lime and fertilizer were spaded and mixed in the soil to a depth of 6 inches and the soil allowed to stand for two weeks before seeding. In order to determine the effect of the treatments, cowpeas were grown as

FIG. 70.

A view of the Mount Vernon garden on which the fertilizer aldehyde experiment was made. Note the unhealthy appearance of the rose bushes.

the test crop. Sixty-eight plants grew in each bed. They were planted May 26, 1916.

A laboratory examination of the soil from each plot, made several weeks after the fertilizers were applied, showed that the two plots to which lime was added were alkaline in reaction and the untreated and acid phosphate plots were neutral.

By July 1 the peas had made considerable growth. The plants on the differently treated plots were showing marked variation. At this time the growth on the untreated plot and that on the limed plot were about equal. The acid phosphate plot was much better—

approximately 20 per cent. better than the check. The plants were taller and the foliage more dense. The plot fertilized with both acid phosphate and lime was the best in the series; it was even better than the acid phosphate plot.

Photographs were taken at this time and are shown in Figs. 69, 70, and 71. Fig. 69 shows the flower garden in which the experiment was made, and a near view of the cowpeas growing

FIG. 71.

Effect of acid phosphate on cowpeas on a soil containing salicylic aldehyde.

in the soil experiment. Fig. 70 shows another section of the flower garden, with the soil experiment in the background near the box hedges. These two pictures show the arrangement of the rose beds encircled by a border of violets. The box hedge encloses the flower garden. The poor and straggling condition of the roses can be seen in each picture. A close view of the cowpeas is shown in Fig. 71. The comparative growths of the cowpeas on the check and acid phosphate plots are readily seen, and it is apparent that growth on the phosphate plot is much larger.

The cowpeas were cut and the weight of vines taken on July 19. The results are given in Table XXIII.

TABLE XXIII.

Effect of Lime and Phosphate on Cowpeas in a Soil in Which Salicylic Aldehyde Formed and Remained for Several Years.

Treatment	Green weight per plot Grammes	Per cent. increase
Soil untreated	2600	—
Soil + lime	2750	2
Soil + acid phosphate	3770	40
Soil + acid phosphate + lime	4070	51

Lime alone did not seem to benefit this soil very much; there was an increase of only 2 per cent. in growth on the limed plot. The acid phosphate, however, produced 40 per cent. increase, and the acid phosphate and lime together 50 per cent. increase. As shown by this experiment and former work on this soil, conditions for growth are much improved by the addition of phosphate fertilizers and sufficient lime to prevent acidity. A thorough underdraining of the soil is essential. The improved drainage system installed permits of better aëration and consequently better oxidation. The heavy applications of stable and other organic manures which the soil received for years were discontinued. Fertilization with phosphates and lime, together with improved drainage, has rid the soil of harmful aldehydes, at least temporarily, and made it a better soil for crop growth. While it has been shown that the aldehydes no longer existed in the soil, it will be necessary to examine the soil from time to time to ascertain whether or not it will again be formed.

SUMMARY AND CONCLUSION.

The experimental results show that aldehydes are harmful to plant growth in aqueous culture solutions, in nutrient solutions, in soil in pots, and in soil in the field.

The effects of six aldehydes—namely, salicylic aldehyde, vanillin, benzaldehyde, heliotropine, formaldehyde, and paraformaldehyde—were studied in nutrient-culture solutions and each proved to be detrimental to plant growth.

The effect of the compounds varied according to the com-

position of the nutrient solutions. Salicylic aldehyde was least harmful in solutions composed of a high percentage of phosphates. Vanillin was least harmful in solutions with a high percentage of nitrates. Benzaldehyde was about equally harmful in all the nutrient solutions. It was slightly more harmful, however, in the high nitrate solutions than in the mainly phosphatic or potassic cultures. Paraformaldehyde was also least harmful in the phosphate culture, but formaldehyde and heliotropine showed harmful effects to an equal degree in almost all cultures, regardless of their composition.

Salicylic aldehyde and vanillin were found to occur in soils quite frequently, especially in soils of low productivity. The isolated substance from the soils was harmful to plants when dissolved in aqueous solution.

The two aldehydes were harmful in some soils and not in others. The field studies show that the added aldehydes disappeared in some soils and not in others. There was no harmful action where the aldehydes were destroyed. The soils in which the aldehydes were destroyed have strong biological activities, good oxidation powers, and are fertile.

The results of the experimental work presented in this paper further show that unfertile soils, where due to the presence of harmful aldehydes, can be made productive by good drainage and by the use of lime and certain fertilizers. This is demonstrated, *first*, by the growth of plants in nutrient solutions, where it is shown that phosphates partially overcome the bad effects of salicylic aldehyde, and that nitrates ameliorate the harmfulness of another aldehyde, vanillin. *Second*, by the more normal absorption of phosphates by plants growing in solutions containing salicylic aldehyde. *Third*, by the growth of plants in soil in pots, which shows that the harmful action of salicylic aldehyde is partially overcome by lime and phosphates and the effects of vanillin by lime and nitrate fertilizers. *Fourth*, by the growth of plants in field soils to which aldehydes were added, which again shows that lime and phosphates lessen the harmfulness of salicylic aldehyde and lime and nitrates alter the effects of vanillin. *Fifth*, by chemical tests in which it was shown that salicylic aldehyde, when added to a soil, was destroyed where lime and phosphates were added, and vanillin was destroyed where lime and nitrates were added. *Sixth*, by the improved productivity from the addition of

lime and phosphates to a soil in which salicylic aldehyde was naturally formed and persisted for a period of years.

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Kelp. A. W. STOCKETT (U. S. Bureau of Mines).—For many years kelp has been recognized as a vaulable fertilizer, and has been used in this country and Alaska. Recently the Bureau of Soils has conducted an investigation of the extent and availability of giant kelp beds on the Pacific coast, and an appropriation of $175,000 was granted to the Department of Agriculture. A plant has been erected at Summerland, Cal., for demonstrating on a commercial scale the various processes of extracting potash and by-products from kelp. It has been estimated that there is on the Pacific coast, from Cape Flattery to San Diego, sufficient kelp to furnish 250,000 to 400,000 tons of K_2O per year. All of this, however, is not available, as in many places the kelp grows in exposed positions not readily accessible to machine cutters, and not within practical working distance of suitable harbors.

Several plants are now operating on the California coast, and the output from this source ranked second in 1917. The kelp is harvested by machine cutters on barges, and brought to shore, where it is either dried and ground, or reduced to a char, which may be used direct as a fertilizer material, or treated to produce a high-grade potassium chloride. The dried and ground kelp is a suitable material for use in mixed fertilizers containing not more than 6 per cent. of K_2O, but this source of supply can hardly be regarded as permanent under normal conditions. Figures of cost of production are not available, but from information received it seems that potash from kelp can not be produced at less than $2 per unit. The geographic situation of the kelp beds is unfortunate, as less than 1 per cent. of

the fertilizer consumed is used west of the Rocky Mountains, and freight rates to eastern points would be prohibitive. The freight rate per unit of K_2O on the dried and ground kelp would amount to about $2, on the kelp char to about $1, and on the high-grade chloride to about 60 cents. No figures for freight rates via the Panama Canal are available. Attempts to transplant kelp from the Pacific to the Atlantic coast have so far been unsuccessful, as no suitable localities have been found, and the prospect of success of such a project is not considered promising.

Dust from Blast Furnaces. A. W. STOCKETT (U. S. Bureau of Mines).—The recovery of potash as a by-product in the manufacture of pig-iron was first investigated by R. G. Wysor, at the plant of the Bethlehem Steel Company. Dust settling in the stove and boiler passes was collected, and was found to contain nearly 10 per cent. of K_2O. Investigation showed that the potash recovered from this dust was only a small proportion of the total in the charge, being less than 2 per cent., and that 67 per cent. of the potash was lost in the primary washers and in the stack gases. Experiments with electrical precipitation proved that practically all of the dust could be precipitated successfully. A plant for collecting the dust is now being erected at a 400-ton furnace at the Bethlehem Steel Company's plant at Lebanon, Pa., and another plant is to be built in Alabama at an early date. Mr. Wysor states: "I venture to predict that in the future dry cleaning will be adopted in many blast-furnace plants, and that many thousands of tons of potash, hitherto wasted, will be reclaimed." Mr. Charles Catlett has said: "It is easy to remove the fumes and dust from the gases without interfering in any way with the operation of the furnace. The investment would be moderate, and the cost of operation of the potash-recovery plant low, while the gases would be improved for use in the stoves."

An investigation is being made to determine the total amount of K_2O lost in the dust of all the furnaces in the United States, but the figures are not yet available. Probably, however, the amount recoverable will exceed the total requirements of the country. Without taking into account the indirect advantage of cleaner gas for use in the stoves and gas engines, it may be safely stated that potash can be obtained from this source at a price that will enable it to compete successfully against the German potash under all conditions.

The iron industry, like the cement industry, is situated near the principal centres of demand for fertilizers, and should receive every inducement from the Government to erect plants for the recovery of potash, as it seems probable that these two industries could be made capable of permanently supplying the entire potash requirements of the country at a price that would encourage the more extended use of potash as a fertilizer, and thus increase the food supply.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

VARIANCE OF MEASURING INSTRUMENTS AND ITS RELATION TO ACCURACY AND SENSITIVITY.[1]

By Frederick J. Schlink, Associate Physicist.

[ABSTRACT.]

INSTRUMENTAL variance, which forms the major part of the discussion of this paper, is a factor whose effect in causing error in measuring instruments has hitherto been given but little consideration. In order to bring out the essential relations of variance characteristic, the paper opens with a discussion of accuracy and sensitivity, showing how each of these terms can be given precise definition with definite numerical significance. Such values when determined have important use in establishing the figure of merit or value of a given instrument or type of instrument. A distinction is drawn between the commercial accuracy commonly called for in direct reading instruments of the shop and plant, and the higher grade of accuracy required in the laboratory where commercial indications are normally subject to the application of corrections for error of calibration.

The error arising from whatever source, observed in an indication of the instrument, divided by the true value of the measured quantity, may be termed the *inaccuracy* at a given reading, the negative term being justifiable on the basis of custom and ease in application. The *accuracy* will be the reciprocal of the quantity just defined. The observed *error* of an instrument (or the correction) is utilized for adjusting observations before their use in calculation, while the *inaccuracy* and *accuracy* find their utilization in rating the quality or performance of the instrument.

An instrument is understood to be sensitive when it shows a change of reading for any change in the quantity being measured, a definition having little significance until means are available for expressing the sensitiveness numerically. Attention is called to the common inconsistencies in the sensitiveness rat-

* Communicated by the Director.

[1] Scientific papers No. 328.

ings of familiar instruments and the suggestion is made that the unit of response, which is referred to the unit of change in the measured quantity in establishing the value of the sensitivity, should be based upon a definite and inherent characteristic of the instrument rather than upon an accidental factor such as the length of a pointer or an arbitrarily graduated scale. Thus in the case of an analytical balance, sensitivity should be referred, not to motion at the tip of the pointer but to the angular deflection of the beam (or pointer), so that comparison can be made of the true equilibrium properties of balances without reference to the accidental and unimportant factor of pointer length, which, within reasonable limits, is alterable at will. In a balance then the sensitivity would be determined as the angular deflection of the rest position of the beam per unit addition of load to the load pan, the first expressed in radians and the second in grams.

The necessity for distinguishing between insensitiveness and passiveness or sluggishness in an instrument is shown and consideration is given to the effect of friction in preventing response to certain small changes in the measured quantity, such that if the usual definition of sensitivity were accepted, we would find a phase of zero sensitivity followed by one of finite sensitivity, consequent upon the overcoming of the static friction which tends to prevent immediate response. Such a discontinuity in the value of sensitivity being irrational, in view of such a determination being dependent upon the absolute rather than the relative values of the quantities entering into the observation, we must modify our definition of sensitivity to this form: sensitivity in an instrument is the rate of change in the indication of such instrument with respect to change in the quantity being measured, it being necessarily assumed for the purposes of this definition that friction and lost motion in the mechanism have been eliminated or are negligible. The amount of the least alteration in the value of the measured quantity, producing instrumental response, divided by the initial value of the measured quantity may be called the *passivity* of the instrument at that point. Passiveness is a special case of the phenomenon of variance, next discussed.

Variance is defined as the range, at any given value of the measured quantity, or variation in reading which may be exhibited by the instrument under repeated application of the same

value of the quantity being measured, after a steady reading has been attained,—the environment remaining unchanged.

The specific variance or *variancy* may be defined as the ratio of the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured,—divided by the measured quantity itself, the same assumptions applying as above as to the attainment of a steady state of indication and as to the maintenance of unchanged environment.

Determination of the variance is a most important part of the calibration of an instrument and appreciable error may arise from failure to recognize or express it. The paper illustrates the derivation of the variance from the hysteresis loop obtained when an instrument is subjected to a complete cycle of operation from a lower to a higher indication, and return,—while plotting point by point the instrumental readings (or corrections, or errors) against actual values of the quantity being measured. The importance of a study of this loop in analyzing instrument performance is shown, and figures are presented to exemplify the type and magnitude of the effect.

The sources of this hysteresis phenomenon are discussed, including the inelastic actions of certain force-equilibrating elements, and, at greater length, the purely mechanistic cause comprised in backlash. In illustrating this latter defect, the importance of maintaining constant or definite space relationships in the instrument linkwork is set forth, and detailed consideration is given to one of the most common causes of imperfect reversibility in instruments, that of the shifting zone of contact in a bearing whose journal fits in a slack or imperfectly constrained manner. The existence of mechanistic causes of irreversibility quite distinct from the ordinary concept of backlash is demonstrated, in the rolling of the pin or journal about the interior face of its slack bearing in a significant and fairly definite manner, capable of kinematic analysis and accounting satisfactorily for phenomena usually ascribed to the operation of frictional resistances simply. It is shown moreover that this cause produces an actual alteration and variation of the magnification or displacement ratio of the instrument from the point of reception to the point of registration of the quantity being measured.

The frequency curve method of delineation is applied to the expression of variance of an irregular nature, as found in instruments exhibiting bad workmanship or ill repair, and it is seen that the variance characteristic of such an instrument can be completely defined by reference to a family of frequency curves obtained in the following manner: One series of points will be plotted for readings taken at varying rates and amounts of increase of the measured quantity terminating in the value corresponding to the particular point of the scale under investigation, and another set for decreasing values terminating at the same point. Such a curve, in which frequency of occurrence of a particular reading or error is plotted against the true value of the measured quantity at that reading, gives the probability of occurrence of any amount of variation from, say, the mean instrumental reading.

Far from being a relatively unimportant source of inaccuracy in measuring instruments, it can be shown that the hysteresis or variance type of error demands consideration in practically every type of instrument, while in some (such as pointer-and-dial types of displacement-indicators) it is a preponderating factor in design and actually limits the application or utility of the instrument and sets the limit of sensitivity and accuracy practicably to be obtained.

Only brief consideration is given to the phenomenon of instrumental drift, which, having its source usually in elastic after-effects, requires special treatment from the point of view of the elastician.

A few means of reducing instrumental variance are given, including the use of special types of bearings in which slack or clearance can be reduced to a minimum without impairing easy operation; and the use of flexible elastic connectors between elements of the linkwork, instead of gears and racks or pin-and-link connectors. Such tape-like connectors which may wind on cam-shaped members to provide for correction of displacements to a linearly graduated scale, exhibit excellent properties in the matter of reversibility of calibration, and have important advantages over the more usual types of linkwork details.

The action of vibration in reducing instrumental variance is found to accord well with the principles previously set down, and it appears that, within limits, errors of result due to mechani-

cal sources of variance can be considerably reduced by judiciously applied vibration treatment.

In designing and constructing an instrument, due consideration should be given to the effect of variance errors in practically limiting the sensitivity to be sought in adjustment, as well as the interval between the graduations and the smallness of the units of graduation. It is suggested that in view of this condition, the mean interval of graduation of laboratory instruments should not be less than five times the mean variance, while for commercial or plant instruments the ratio of mean scale interval to mean variance may be of the order of two to one. Likewise the sensitivity may easily be disadvantageously high, inducing erroneous estimates of the precision of results and requiring special care in the calibration and use of the instrument.

The factors of maximum or mean inaccuracy, (or accuracy) sensitivity, variancy and specific set (the amount by which the variance loop may fail of closure, divided by the range of the deflection cycle) may be referred to the total range of graduation instead of to particular values of the measured quantity under observation, as a convenient means of arriving at single significant numbers to be composed into a "figure of merit" for an instrument whose characteristics are being determined.

Persons having problems of instrument design on hand who may be desirous of obtaining copies of the full paper in advance of its publication, may do so by application to the author, at the cost of blue-print reproduction of the manuscript (34 pages and 7 figures).

MEASUREMENTS ON THE INDEX OF REFRACTION OF AIR FOR WAVE-LENGTHS FROM 2218A TO 9000A.[3]

By W. F. Meggers and C. G. Peters.

[ABSTRACT.]

A SURVEY of previous researches on refraction of air shows that many investigators have worked either with white light or with one monochromatic radiation, and dispersion measurements have been limited to a small interval of the spectrum. No index measurements exist for waves longer than those corresponding

[3] Scientific papers, No. 327.

to orange light, and in the ultra-violet the dispersion formulæ disagree by more than 10 per cent. of the refractivity.

Recent work in spectroscopy makes it very desirable to have more accurate and extensive data on the index of refraction and dispersion of air. The international system of standard wave-lengths expresses the lengths of waves in air at 15° C and 760 mm., and all wave-length measurements made under other conditions require small corrections because of the effect of temperature and pressure of the air upon its optical dispersion. Furthermore, it is often desirable to multiply wave-lengths measured in air by the indices of refraction of air for these wave-lengths and thus convert them to their value in a vacuum. An accuracy of one part in several millions is now striven for in the measurement of wave-lengths and to maintain their relative accuracy in the reduction to vacuum values it is necessary to know the indices of refraction within a few units in the seventh decimal place.

For several years the Bureau of Standards has been engaged in the accurate measurement of wave-lengths. Interferometer comparisons of standard wave-lengths have been made throughout a large range of spectrum and the grating spectra of more than fifty of the chemical elements have been photographed and measured in the red and infra-red spectral regions. In connection with these accurate measurements of wave-lengths it was thought advisable to measure the absolute indices of refraction of air for the entire spectral region which is accessible to photography.

Accuracy and efficiency recommended the use of the Fabry and Perot interferometer for this work since this apparatus can be conveniently enclosed in a chamber in which the temperature and pressure of the air can be regulated as desired, and it also permits simultaneous observations for a large number of different wave-lengths. Sections of the circular fringes, produced by various radiations from a source of light illuminating the parallel plates of the interferometer, were photographed either with a grating or a rock salt prism spectrograph, first when the space between the plates was evacuated, and then when dry air at measured temperature and pressure was present.

The index of refraction for a particular wave-length was obtained directly from measurements of the photographed interference fringes which allowed the ratio of lengths of this wave

in vacuum and in air to be calculated. Observations were made at spectrum intervals of about 40 A from the extreme ultra-violet at 2200 A, through the visible spectrum and in the infra-red to 9000 A.

Complete sets of observations were made on dry air at atmospheric pressure and at temperatures of 0°C, 15°C and 30°C.

These are quite closely represented by the following dispersion formulæ of the Cauchy form.

$$(n-1)_0 \times 10^7 = 2875.66 + \frac{13.412}{\lambda^2 \times 10^{-8}} + \frac{.3777}{\lambda^4 \times 10^{-16}}$$

$$(n-1)_{15} \times 10^7 = 2726.43 + \frac{12.288}{\lambda^2 \times 10^{-8}} + \frac{.3555}{\lambda^4 \times 10^{-16}}$$

$$(n-1)_{30} \times 10^7 = 2589.72 + \frac{12.259}{\lambda^2 \times 10^{-8}} + \frac{.2576}{\lambda^4 \times 10^{-16}}$$

These observations are used in the construction of a table giving the corrections which must be applied to wave-lengths measured in air where density is not normal. A table of corrections to convert wave-lengths or frequencies measured in air to their values in a vacuum is also given.

The coefficient of index variation with temperature was found from these measurements to be a function of the wave-length. For long waves this optical temperature coefficient is identical with the density temperature coefficient, *i.e.*, $\frac{1}{273}$ but as the ultra-violet absorption band is approached it increased rapidly, becoming $\frac{1}{258}$ at 2500 A.

There seems to be no definite evidence of any strong absorption of infra-red light by dry air and it is therefore possible to represent the optical dispersion of air by the first term of Sellmeier's formula quite satisfactorily.

THE INFLUENCE OF QUALITY OF GAS AND OTHER FACTORS UPON THE EFFICIENCY OF GAS-MANTLE LAMPS.[1]

By R. S. McBride, W. A. Dunkley, E. C. Crittenden, and A. H. Taylor.

[ABSTRACT.]

THIS paper describes the apparatus and methods employed and the results obtained in studying the effects of several variables such as gas pressure, gas adjustment, air adjustment, and gas

[1] Technologic papers, No. 110.

quality upon the performance of various types of gas mantle lamps. Several tables and curves are given to assist in the presentation of the results.

The experiments show that if the pressure of gas supplied to a mantle lamp is increased above the minimum pressure at which the lamp will operate, other conditions remaining the same, a regular increase in gas consumption is observed. The candlepower and efficiency of the lamp also increase until maxima are reached, the efficiency attaining its maximum first. Further pressure increases results in decreases in the efficiency and candlepower. Within the pressure range tested (1½ to 8 inches of water) it was found that pressures of from 2 to 4 inches gave the highest efficiencies regardless of the pressure at which the lamp was adjusted to give maximum candlepower.

The effect of gas adjustment changes was found to be similar to the effect of pressure changes. It was found that if a lamp which had been adjusted to give maximum candlepower at a given pressure, was readjusted so as to use slightly less gas, the efficiency usually increased somewhat. It was also found that the adjustment devices on various lamps had markedly greater effects on lamp performance in certain portions of their ranges than in other portions.

The effects of air-shutter adjustment depended upon the quantity of gas being used. In general the gases of higher heating value required the lamp to have greater air shutter opening to give maximum efficiency than did the gases of lower quality.

It was found that if a lamp was given the most favorable adjustment when burning each given quality of gas, there was little difference between the various efficiencies obtained. In comparing city gas (mixed coal and water gases) of about 650 Btu with water gas of about 540 to 575 Btu it was found that the latter gave slightly higher efficiencies in upright type of lamps. In the comparison of coal gas and water gas, each of about 540 Btu it was found that in nearly all cases there was slight advantage in efficiency for the water gas. City gas enriched with benzol from about 650 to 740 Btu gave somewhat higher efficiencies in upright lamps than did the unenriched gas. Natural gas burned in lamps designed for it gave efficiencies about 20 per cent. lower than did manufactured city gas burned

in artificial-gas lamps of similar type. The conditions did not, however, permit of as great exactness in this determination as in those previously mentioned.

Selecting the maximum candlepower and efficiency points in several tests with various cases and studying these values in connection with the rates of heat input at which they were obtained, it was found these maximum points were distributed over a very wide range of heat inputs. It was found that in general these maximum values were not determined by rates of heat input at which they occurred. On the other hand, a maximum candlepower obtained in a given test was likely to be higher if it was accompanied by a high rate of heat input. It was found that it was practically impossible to control all the conditions affecting a mantle lamp with sufficient exactness to ascertain a most efficient rate of heat input.

METRIC MANUAL FOR SOLDIERS.[4]

The aim of the metric manual is to give to the American soldiers the grasp of the metric system which will enable them to think and work in metric units.

As recommended no tables of equivalents need be memorized. Brief tables and a vocabulary are given for reference. The units are described by actual examples likely to be encountered in military work.

Heavy Mallet Locomotive for Norfolk & Western Railway. Anon. (*Engineering News-Record*, vol. 81, No. 20, p. 898, November 14, 1918.)—A Mallet locomotive with a weight of 535,000 lbs. without tender or 747,000 lbs. with tender has been built for the Norfolk & Western Railway. There are eight drivers on a side, with a total driving wheel base of 57 ft., 4 in. The weight on the drivers is 472,000 lbs. The weights on the leading truck and trailing truck are respectively 28,000 and 35,000 lbs. The total wheel base is 92 ft., 11¼ in. The tender, which weighs 212,000 lbs., has a water capacity of 12,000 gallons and a coal capacity of 20 tons.

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[4] Miscellaneous Publications, No. 21.

Freeing the Range Country and Forest Reserves of Predatory Animals. (*U. S. Department of Agriculture*).—Skilled hunters in the employ of the Government are waging persistent warfare against the predatory animals that prey on sheep and cattle in the Western States. Their efforts are encouraging stockmen to increase live-stock production on the Federal forest reserves as well as in the range country, and they are protecting the sources of war supplies of meat, leather and wool now in the Western grazing districts.

Hunters of the Biological Survey of the United States Department of Agriculture have killed 70,713 predatory animals during the last three years, which has resulted in a direct saving estimated at nearly $5,500,000 a year to the stockmen of the Rocky Mountain section. The total kill since the fall of 1915, when the work was started, includes 60,473 coyotes, 8094 bobcats, 1829 wolves, 201 mountain lions and 137 bears. The Government experts estimate that the annual depredations among cattle and sheep effected by single predatory animals are as follows: Wolf, $1000; stock-killing grizzly bear, $500; mountain lion, $500; bobcat, $50, and coyote, $50.

Stockmen in sections where the predatory animals are obnoxious are aided by the Government in ridding the ranges of them. In some localities the stockmen's associations coöperate with the State and Federal authorities in the extermination campaign, professional hunters being employed to detect and kill the prowling animals that prey on sheep and cattle. Illustrative of the scope of this work, the total income from pelts of predatory animals killed by Government nimrods last year amounted to approximately $100,000. In addition, many other animals, whose skins could not be reclaimed, were killed by poisoning. Ordinarily the United States Biological Survey has from 250 to 350 professional hunters permanently in its employ. The area wherein predatory animal control is practiced includes ten districts: Montana, Idaho, Washington and Oregon, Nevada and California, Utah, Wyoming and South Dakota, Colorado, Arizona, New Mexico, and Texas.

During the last twelve months 26,226 coyotes, 3458 bobcats, 849 wolves, 85 mountain lions, and 41 stock-killing bears have been disposed of, at an annual saving of approximately $2,400,000 in domestic stock.

Recently a Government hunter shot two male wolves which had killed 150 sheep and 7 colts on two Wyoming ranches, while another trapper bagged a pair of old wolves which had a record of killing $4000 worth of live stock a year. A third trapper destroyed 85 coyotes and 2 bobcats in one month, using 6 horses and 200 traps over a trap line varying from 50 to 100 miles in length. A coyote was recently captured which had destroyed $75 worth of sheep in one week. Two wolves, seven mountain lions, and a huge grizzly bear, the largest of its species ever killed in the Yellowstone Park section, are the kill of another Government sharpshooter. These results are typical of the campaign destined to free the Rocky Mountain range country of predatory animals.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

RATE OF PUPILLARY DILATATION AND CONTRACTION.[1]

By Prentice Reeves.

[ABSTRACT.]

AN examination of the literature showed very little available material on the operation of the normal pupil. In the first part of this experiment instantaneous flashlight photographs were taken of the pupils of two subjects for eight brightness levels, including total darkness at one end and the just tolerable reflection of full sunlight from white paper at the other end. The effect of exposing one or both eyes to the sensitizing field was determined for both subjects throughout the brightness range.

From these curves six brightness levels were chosen and the pupils of six subjects were measured, one of the first subjects being used in this series to check the method. In this part of the experiment a motion picture camera was used and a lamp bank displaced the flashpowder.

The rate of closing of the pupil was measured by taking motion pictures of an eye fully adapted to darkness, hence maximum diameter, as it closed to a diameter almost its minimum. The same six subjects served, as well as two others, and the average pupil closed in less than five seconds. The greater part of the contraction occurs within the first two seconds.

The rate of opening was determined for seven subjects, the above six and one other, as the pupil opened from near a minimum to a maximum diameter. The average pupil required from three to ten minutes to reach its maximum diameter.

The curves plotted of these results are similar in shape, though marked individual differences are shown as well as variations in the results from the same subject on different days.

* Communicated by the Director.

[1] Communication No. 66 from the Research Laboratory of the Eastman Kodak Company, published in *Psychological Review* 25, 1918, p. 330.

Dust from Cement Works. A. W. STOCKETT (U. S. Bureau of Mines).—The first cement plant to recover potash from the kiln dust was that of the Riverside Portland Cement Company, in California. Owing to litigation with near-by fruit growers who claimed that the fine dust escaping from the kilns was causing damage to the fruit trees, the company was compelled to install an electrical dust-precipitating plant to abate the alleged nuisance. Analysis of the dust thus collected showed that it contained about 10 per cent. K_2O. The dust collector was completed early in 1913 and has been continuously and successfully in use ever since. What was originally considered an additional expense in the manufacture of cement has proved to be a highly profitable by-product.

Another plant is successfully using the same method at Security, Md., and both electrical precipitation and other methods of collecting dust are being used at different plants. A point in favor of dust collection is that no change in present methods of manufacturing cement is involved, and at one plant the installation has led to a reduction of 10 per cent. in fuel consumption, owing to the more careful attention required in burning the cement.

An investigation recently completed by the Bureau of Soils indicated that the probable maximum amount of potash that might be recovered from all the cement works in the country would be 100,000 tons of K_2O per year. It is not likely that dust-collecting plants will ever be installed at all cement works, but it seems reasonable to expect that the amount of K_2O to be derived from this source should reach 50,000 tons a year, or 20 per cent. of the total normal requirements. Probably this amount could be increased somewhat by using, where available, rock containing more K_2O in the raw mix.

An objection raised to cement-kiln dust as a source of potash in manufacturing fertilizers is that if used in large quantities the lime content will cause reversion of the soluble phosphoric acid in the phosphate and loss of the ammonia in ammonium sulphate. The K_2O content of cement-kiln dust is also too low to permit its use as the only source of potash in a fertilizer that is to contain more than 3 per cent. of K_2O. However, these objections can easily be overcome, and some potassium sulphate containing 40 per cent. of K_2O is now being marketed by one of the cement works.

Published figures on the cost of production show that, allowing for the amortization and interest on investment, potash can be produced by the cement companies at 30 to 50 cents a unit of K_2O, which will enable them to compete successfully with the German salts even at pre-war prices.

Thus the cement industry, especially in view of its geographical situation, seems one of the most promising sources of a permanent American supply of potash, and the Government should offer every possible encouragement to install plants for the recovery of potash, especially in cement works east of the Mississippi, as more than 90 per cent of the commercial fertilizer used in the United States is consumed in that area.

NOTES FROM THE HESS-IVES LABORATORIES.*

A NEW PHOTOGRAPHIC MORDANT DYE PROCESS.

By Frederic E. Ives.

THE first photographic mordant dye process to attract attention was the silver-iodide process of Dr. Traube (U. S. Pat. 1,093,503, 1914). Metallic silver photographic images converted to silver iodide and immersed in solutions of basic dyes become strongly colored. If the dye is then fixed by tannin, the silver-iodide can be dissolved out, leaving a transparent dye image. Traube's method was improved upon by Tauleigne and Mazo (U. S. Pat. 1,059,917, 1913), who showed how to produce a silver-iodide image having a stronger affinity for the basic dyes, and incidentally that by first hardening the gelatine with alum and then treating the silver-iodide image with a strong solution of potassium iodide it was made so transparent that for most purposes it was unnecessary to dissolve out the silver-iodide image. The step of hardening the gelatine in alum to prevent it from softening and dissolving in the strong potassium iodide solution was omitted in the United States patent specifications, but was published in the *British Journal Photographic Almanac*, 1912, page 653. Hoyt Miller (U. S. Pat. 1,214,940, 1917), as a result of experiments with the process without alum hardening, declared the process unworkable, and broadly claimed the production and dyeing of a transparent silver-iodide image, he hardening the gelatine with formalin. I have myself operated the Tauleigne-Mazo process with perfect success.

Incidentally it had been discovered that silver ferrocyanide, silver chromate and some other silver salts could be similarly dyed, but not with satisfactory results. Fox (U. S. Pat. 1,166,-123, 1916), disclosed the fact that a vanadium-toned silver image mordanted basic dyes, and Crabtree and Ives (priority to Crabtree) independently discovered that a copper-toned image had the same property to a very notable and useful degree. The copper-toned image, like the transparent kind of silver-iodide image, is sufficiently transparent for most purposes without "fixing out,"

* Communicated by the Laboratories.

but can be made perfectly transparent by fixing "hypo" without first fixing the dye image with tannin. It has the disadvantage for some purposes that the copper-ferrocyanide image is itself colored (red-brown) and will not serve as the base for pure blue and green images. It has proved perfectly satisfactory for the production of orange-red images in combination with a cyanotype print in the same colloid layer in my colored moving picture process (U. S. Pat. 1,278,668, 1918).

Recently, I have discovered a new method of producing mordant-dye photographic images, which I think is superior to any heretofore known. The mordant is a chromium compound the exact nature of which I have not yet determined, but it is not silver chromate, which is of a deep red color, while the image which I produce previous to dyeing is of a very pure, though pale, yellow color. It is produced very simply, quickly and cheaply, by bleaching the silver image in a solution of equal parts of potassium ferricyanide and chromic acid, the action of which is analogous to that of potassium iodide in that if the solution is weak the image is not transparent, but if the solution is strong, the image is perfectly transparent and of a pale, though pure yellow, color. It is necessary to wash out the free chromic acid after bleaching. The pale yellow image thus produced has a much stronger affinity for some of the basic dyes than either silver iodide or copper ferrocyanide. In fact, the silver image, for the best results, must be thin and superficial.

My bleaching solution is made with one ounce each of potassium ferricyanide and chromic acid in one gallon of water, at which strength it acts very quickly and produces a transparent yellow image. Transfer to running water should be made immediately when the image is completely bleached, to avoid overhardening of the gelatine by the chromic acid. Long washing is necessary to clear out the free chromic acid, but it discharges rapidly in water containing a little soda bicarbonate, and the image also dyes up quicker and clears more rapidly after dyeing if the soda bicarbonate is used. I always use it, but too long immersion whitens the image, reduces its transparency and produces a weaker, though still strong and brilliant dye image.

A typical dye bath is made by dissolving 10 grains of saffranin in 4 ounces of alcohol and adding it to one quart of water made slightly acid with acetic acid. For complete dyeing, an immersion

of half an hour or more may be necessary. This will stain the entire film deeply, after which it may be cleared by washing in water containing a very little acetic acid. Other very active dyes are malachite green and auramine.

The images which have been whitened by long soaking in soda bicarbonate solution have the same appearance and transparency as silver ferrocyanide images, but have many times more mordanting power—more even than silver iodide.

The Sign of Potentials. O. P. WATTS. (*Proceedings of the American Electrochemical Society*, September 30–October 2, 1918.)—A phenomenon which attracted much attention from the early electrochemists was the displacement of metals from solution by other metals. The relative displacing power of many of the elements was thus measured, and they were arranged in the order of their power of precipitating other metals; this constituted the electrochemical series. Electrochemists, however, have not been satisfied with mere order, but have measured and expressed in volts the distances between different metals, so that the old electrochemical series has been converted into the modern table of potentials. In spite of their inaccuracy and the very limited number of electrolytes in which the potentials of metallic conductors are as yet known, these tables have proved of the greatest value in explaining the phenomena encountered in electrolysis, and in successfully predicting what will happen when certain electrodes are employed in a particular electrolyte.

According to these tables, magnesium, zinc, etc., are electro-positive metals, while platinum and gold are highly negative. If a voltaic cell be formed by using two of the above metals as electrodes in a chlorine solution, the flow of current through the electrolyte will be from the metal of higher potential to that of lower potential, and the E.M.F. of the cell will be equal to the difference of potential between the metals.

For many years this convention regarding the use of signs was unanimous, and writers on electrochemical subjects either gave such a table or referred to zinc, etc., as electro-positive. In works on the corrosion of iron, dating from 1822 to 1918, wherever stimulation of rusting by local action was mentioned, the iron was said to be positive to the copper, graphite, or whatever constituted the other electrode of the cell. Similarly, the protective action of zinc was ascribed to its being electro-positive to iron.

In the gravity cell, we consider what is called an electric current as passing from the positive zinc plate through the electrolyte to the negative copper; and because electricity flows only in closed circuits it must return to the zinc through the wires, etc., which constitute the remainder of the circuit. The terminal of an ammeter,

voltmeter, or other D. C. electrical instrument by which the current should enter is marked by a plus sign, and, therefore, must be connected to the copper plate to receive the current that passes through the electrolyte to this electrode. The futility of attempting to represent completely the electrical conditions in a voltaic circuit by attaching a single sign to either electrode was recognized by the early electrochemists when they spoke of the zinc as "the positive plate" (we should now say electrode), "but the negative pole of the cell." There is yet to be found a simpler way of designating the relation of the zinc electrode to the whole electrical circuit; for the current will flow from the zinc into the electrolyte, provided that it is permitted to return to the zinc again from that portion of the circuit which lies outside of the cell; yet the driving force resides within the cell.

Faraday gave us the terms anode (up or entering way) and cathode (down or leaving way), and we designate the anode of the electrolytic cell, from which the current enters the solution, by a plus sign, and the cathode, by which it leaves, by the minus sign. The use of signs is the same in the electrolyte as in the voltaic cell—a simple and easily understood arrangement. The table of potentials consists, in accordance with the ionic theory, of the "potential of the solution minus the potentials of the metals." The table as rewritten by those who contend for a change of sign consists of "the potentials of the metals minus the potential of the solution." Since ions of the metals are usually considered to be charged positively, when a strip of zinc, for example, is thrust into an electrolyte, zinc ions go into solution carrying positive charges, therefore lowering the potential of the zinc and raising that of the solution, so that the zinc should be negative to the solution. It would thus appear that the advocates of the minus sign for the potential of zinc are contending for the truth, as opposed to error; but the physicists who have been the most ardent advocates of this change of sign tell us that the whole matter of sign is wrong in electricity; that what we call a positively charged ion has less than the normal number of electrons, and that our negatively charged ions have an excess of electrons, and that the "flow of the electric current is really in the opposite direction to that which is now accepted."

It follows that if the proposed change of sign in potentials be adopted, carrying with it all the confusion which will result in electrochemical literature and the inconsistencies which have been pointed out, we shall still fail to express the truth regarding the potentials of metals, for the latest theory of the nature of electricity leads us to believe that the zinc electrode is really at a higher potential than the electrolyte, and, consequently, the plus, and not the minus, sign correctly indicates the potential. It, therefore, seems for the best interests of electrochemistry that until such time as the scientific world is ready to revise the entire terminology of the electric circuit, the time-honored custom in regard to writing the electrochemical series and tables of potentials should be followed.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting Held Wednesday, November 20, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 20, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 15.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The chairman then introduced Dr. Alfred B. Hitchins, Director of the Ansco Company's Research Laboratory, Binghamton, N. Y., who presented a paper entitled "Modern Applications of Photography." The speaker outlined the present position of photography in science, industry and research work, and discussed its specific applications to spectroscopy, photomicrography, x-rays, bacteriology, medicine, and aerial photography. He described briefly the work of the Ansco Laboratory and its staff and some of the problems under investigation. The subject was illustrated by lantern slides.

A discussion followed the paper, in which Messrs. Levy, Jennings, Koch, the chairman, and others participated.

After a vote of thanks to the speaker the meeting adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard University
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K., Lieut. Com.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., 1st Lieut.	Air Service, U .S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade

Name and rank	Branch of service	Location
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Washington
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington

Name and rank	Branch of service	Location
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Casper W., Major	Medical Corps. Division of Food and Nutrition	Washington
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Pemberton, Henry R.	U. S. Naval Air Service	Key West, Fla.
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.O.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Railway Artillery Reserves	France
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York

Name	Appointment	Location
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Wahington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma

Name	Appointment	Location
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Rittmann, Walter F.	Consulting Chemical Engineer, U. S. Bureau of Mines	Pittsburgh
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting Held Wednesday, November 6, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 6, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2723.—The Prestwich Fluid Gauge.

The following reports were presented for final action:

No. 2722.—The Calorizing Process, Diamond Power Specialty Company, Detroit, Mich.; recommended that the Edward Longstreth Medal be awarded to Tycho Van Allar, of Schenectady, N. Y., and the Certificate of Merit to Emery G. Gilson, of Schenectady, N. Y.

No. 2724.—The Rolin Adjustable Grate, Charles W. Rolin, of Philadelphia, Pa.; recommended that the Certificate of Merit be awarded to Charles W. Rolin, of Philadelphia, Pa.

GEO. A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, November 13, 1918.)

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MR. HUTTON KENNEDY, Manufacturer, Gaul and Adams Streets, Philadelphia, Pa.

NON-RESIDENT.

PROFESSOR B. M. BRIGMAN, Engineering Department, University of Louisville, 119 West Broadway, Louisville, Ky.

LIEUTENANT J. D. JAQUES, C. E. C., U. S. N. R .F., Building 107, Navy Yard, Boston, Mass.

MR. HENRY HOBART KNOX, Mining Engineer, 68 East Eighty-sixth Street, New York, N. Y.

MR. ROLF KNUDSEN, Electro-chemical Engineer, 32 Vandeventer Avenue, Princeton, N. J.

MR. DAVID PELTON MOORE, Patent Attorney, Real Estate Trust Building, Washington, D. C.

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MR. CHARLES H. COLVIN, Mechanical Engineer, 61 Poplar Street, Brooklyn, N. Y.

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MR. FRANK M. ASHMEAD, 816 Ivy Street, Pittsburgh, Pa.

MR. JOHN CALDER, 35 West Thirty-ninth Street, New York, N. Y.

MR. G. E. CHAMBERLAIN, 1650 East William Street, Decatur, Ill.

CAPTAIN THEOBALD F. CLARK, in care of Mrs. Charles Nevin, 2021 Locust Street, Philadelphia, Pa.

MR. C. R. COLLINS, 805 Lowman Building, Seattle, Wash.

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MR. J. GEORGE KLEMM, JR., Haverford, Pa.

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MR. T. E. MITTEN, 1520 Spruce Street, Philadelphia, Pa.

DR. ANNABELLA E. RICHARDS, 2503 Maryland Avenue, Baltimore, Md.

MR. W. H. SHARP, The Wellington, Nineteenth and Walnut Streets, Philadelphia, Pa.

MR. FRANCIS R. WADLEIGH, Room 117, New Interior Building, War Industries Board, Washington, D. C.
MR. J. D. WILLIAMSON, JR., Ogontz, Montgomery County, Pa.
MR. E. H. UTLEY, Vice President, Bessemer and Lake Erie Railroad Company, 727 Union Arcade, Pittsburgh, Pa.

NECROLOGY.

Mr. F. S. Allen, 48 Fairfield Avenue, Hartford, Conn.
Mr. Richard Biddle, Wanderer's Rest, Sewanee, Tenn.
Mr. William Burnham, Morris Building, Philadelphia, Pa.
Dr. E. W. Caldwell, 480 Park Avenue, New York, N. Y.
Mr. James Douglas, 99 John Street, New York, N. Y.
Mr. William L. DuBois, 415 Chestnut Street, Philadelphia, Pa.
Mr. Robert C. Lippincott, 537-39 Land Title Building, Philadelphia, Pa.
Mr. W. J. McCahan, Front and Chestnut Streets, Philadelphia, Pa.
Mr. Marshall Miller, 911 North Eighth Street, Philadelphia, Pa.
Dr. Isaac Norris, Bryn Mawr, Pa.
Mr. F. C. Robinson, 3144 Passyunk Avenue, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

ABRAHAM, HERBERT.—Asphalts and Allied Substances. 1918.
American Electrochemical Society.—Transactions, vol. xxxii. 1917.
BUCHER, E. E.—Vacuum Tubes in Wireless Communication. 1918.
CAMPBELL, ANDREW.—Petroleum Refining. 1918.
FERRY, E. S.; SHOOK, G. A., and COLLINS, J. R.—Practical Pyrometry, 1917.
GILLETTE, H. P., and DANA, R. T.—Handbook of Mechanical and Electrical Cost Data. 1918.
LEUPP, F. E.—George Westinghouse; His Life and Achievements. 1918.
MACELWEE, R. S.—Ports and Terminal Facilities. 1918.
OSBORNE, T. B.—The Vegetable Proteins. 1918.
WHITHAM, J. M.—Water Rights Determination from an Engineering Standpoint. 1918.
WOOD, H. C.; REMINGTON, J. P., and Others.—Dispensatory of United States. Edition 20. 1918.
YOUNG, SIDNEY.—Stoichiometry. 1918.

BOOK NOTICES.

AIRPLANE CHARACTERISTICS: A SYSTEMATIC INTRODUCTION FOR FLYER AND STUDENT AND ALL WHO ARE INTERESTED IN AVIATION. By Frederick Bedell, Ph.D. Ithaca, N. Y., Taylor & Company, 1918, 123 pages, one plate and forty-three illustrations in the text, no index. 8vo. Price, $1.60 net.

This manual is devoted entirely to the mathematical and physical problems of flight in connection with heavier-than-air machines, for which the author

uses "airplane" in preference to the more familiar "aeroplane," a substitution which it is to be hoped will be generally followed. He defines airplanes as flying machines which are "heavier than air, have wing surfaces for support in the air, with stabilizing surfaces, rudders for steering and power-plant for propulsion." Two types are distinguished: "Tractor," in which the propellers are in front of the engine, and "Pusher," in which the propeller is behind it.

The book is liberally illustrated with line drawings showing the principles of stability, equilibrium and other data connected with the art of aviation. An interesting addition to terminology is the expression "parasite resistance," by which is meant all resistance that does not contribute to the lift. A glossary of terms is given in which we note several new words, such as "burble-point" and "yaw," and new uses of familiar words, such as "bank," used as a verb, meaning to incline a plane laterally. The term "dope," of course, appears, but this is now quite familiar in its aviation sense.

The book is stated to be incomplete, a considerable amount of material intended to be included in it not being ready for publication. This will appear, it is hoped, early in 1919. The work will be interesting and useful to the student of the theory of heavier-than-air-machines..

HENRY LEFFMANN.

CENSUS OF DYES AND COAL-TAR CHEMICALS, 1917. Tariff Information Series No. 6, United States Tariff Commission. Washington, Government Printing Office. 1918. 73 pages, 8vo.

This is a very interesting and valuable account of the conditions of coal-tar industries in this country from 1909 to the end of 1917. Space does not permit of an extended summary of the data presented, but some of the facts must be mentioned. Before the opening of the European war but little manufacture of coal-tar products was carried on in this country. A few colors were made, but mostly from the so-called intermediates. Now nearly two hundred firms are engaged in the several lines depending on the utilization of tar. The story of the indigo industry is interesting. It is generally known that for some years before the war the bulk of indigo used in the world at large was made in Germany by synthesis. In 1909 the United States imported over eight million pounds of indigo, of which all but three hundred thousand pounds came from Germany. The price was less than twenty cents per pound. Since the beginning of 1916 no indigo has come from Germany. In that year about three and a half million pounds came from China and over a million from England. The cost was over one dollar per pound. Any one interested in the economic questions growing out of these industries will find the pamphlet of great use. HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Electro-Analysis, by Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. Sixth edition, revised and enlarged, 344 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $2.50.

Technical Books of 1917: Compiled by the Applied Science Reference Department, Pratt Institute, Free Library, Brooklyn, New York. 28 pages, 16mo. Brooklyn, Institute, 1918.

U. S. Bureau of Mines: Efficiency in the Use of Fuel Oil; a handbook for boiler-plant and locomotive engineers, by J. M. Wadsworth; 86 pages, illustrations, plates, 16mo. Monthly Statement of Coal-mine Fatalities in the United States, June and July, 1918; compiled by Albert H. Fay; 2 pamphlets, 8vo. Technical paper 139, Low-rate Combustion in Fuel Beds of Hand-fired Furnaces, by Henry Kreisinger, C. E. Augustine and S. H. Katz; 54 pages, illustrations, 8vo. Technical paper 154, Suggestions for Improved Methods of Mining Coal on Indian Lands in Oklahoma, by J. J. Rutledge and Daniel Harrington; 36 pages, illustrations, plates, 8vo. Technical paper 186, Methods for Routine Work in the Explosives Physical Laboratory of the Bureau of Mines, by S. P. Howell and J. E. Tiffany; 63 pages, 8vo. Technical paper 192, Production of Explosives in the United States during the Calendar Year 1917, with notes on coal-mine accidents due to explosives and list of permissible explosives tested prior to April 30, 1918; compiled by Albert H. Fay; 21 pages, 8vo. Technical paper 197, Use of the Hydrogen-Volatile Matter Ratio in Obtaining the Net Heating Value of American Coals, by A. C. Fieldner and W. A. Selvig; 13 pages, illustrations, 8vo. Technical paper 204, Economic Operation of Steam Turbo-electric Stations, by C. J. Hirshfeld and C. L. Karr; 29 pages, illustrations, 8vo. Technical paper 206, Coke-oven Accidents in the United States During the Calendar Year 1917; compiled by Albert H. Fay, 19 pages, 8vo. Technical paper 208, How to Improve the Hot-air Furnace, by Charles Whiting Baker; 20 pages, 8vo. Washington, Government Printing Office, 1918.

Production of Crude Oil: Letter from the Director of the Bureau of Mines transmitting, in response to a Senate resolution of September 11, 1916, certain information in regard to the production and consumption of crude petroleum and other mineral oils as far as statistics are available; also a letter in response to a Senate resolution of September 13, 1918, transmitting certain information as to what relief the speedy enactment of the bill (S2812) to encourage and promote the mining of coal, phosphate, oil, gas, and sodium on the public domain will give to the threatened shortage in the supply of crude oil. 16 pages, 8vo. Washington, Government Printing Office, 1918.

U. S. Department of Agriculture: Bulletin No. 713. A Study of Farming in Southwestern Kentucky, by J. H. Arnold, Agriculturist. 19 pages, 8vo. Washington, Government Printing Office, 1918.

Concrete Shipbuilding in Spain, 4 pages, illustrations, 8vo. *Concrete Building Block and Brick*, 23 pages, illustrations, 8vo. *Facts About Concrete Roads. The Roads That Help*, 19 pages, illustrations, 8vo. *Concreting in Cold Weather*, 19 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1918.

CURRENT TOPICS.

Developing a Gauging System. E. OBERG. (*Machinery*, vol. 25, No. 2, p. 93, October, 1918.)—One of the most complete systems of gauging for the manufacture of ordnance is that developed by the Pratt & Whitney Company for the manufacture of modern rifles. A modern rifle has from 60 to 125 parts, according to its design, and requires about 700 machining operations for its completion. For that work not less than 1750 working gauges are required. An equal number of inspection gauges are used, and for every inspection gauge there is one reference gauge, so that altogether there are, in one set, 5250 gauges.

Gauging systems and interchangeable manufacturing are so closely related that it would be impossible to discuss one without dealing with the other. The main object in the introduction of interchangeable manufacturing was to reduce costs by standardizing the manufacturing operations and reducing the time required in the assembling of the mechanism. A secondary advantage is thereby gained, of interchangeability of parts. The latter advantage has become an object equally important with the reduction in the cost of assembling. As an example of the reduction of cost in assembling by the adoption of an adequate gauging system, it may be mentioned that the cost of assembling a certain rifle was $2.50. By the adoption of a new tool and gauge equipment, which resulted in the scrapping of the former tool and gauge equipment, valued at $80,000, the cost was reduced to 25 cents.

Interchangeability is sometimes carried too far, when the object sought is merely to facilitate assembling, any further refinement to insure absolute interchangeability involves useless expense. Very few mechanisms, in fact, are absolutely interchangeable. Even in rifle manufacture there are a few cases where matching of parts is permissible, this practice being known as "selective assembling." It is therefore necessary that proper judgment be used in determining upon the importance of interchangeability, and that the various factors be carefully weighed against each other.

It is generally assumed by those who have had no direct experience in devising gauging systems for interchangeable work that it is a comparatively simple matter to determine proper tolerances and limits. It has, however, been proved many times in ordnance and small arms work that without a most careful consideration of the many factors that enter into the production of a part, the cost of manufacture may be increased beyond all reasonable limits. The rule that the designer of the mechanism and the designer of tools and gauges must work constantly together cannot be too strongly emphasized. The most important subdivision of the whole subject

of establishing a gauging system is the determination of suitable tolerances. It should be emphasized that the original design should require as few fits as possible, and liberal clearances should be provided in every case where there is no actual fit.

The first principle that must be considered in the establishment of tolerances—and one that is the most often ignored—is that tolerances should not be determined with reference to what would be the minimum tolerances that could be obtained by modern machining methods; but they should be established with reference to what are the maximum tolerances permissible in the mechanism without interfering with its proper purpose and action. Great difficulty is experienced with designs that do not provide for initial clearance on the original drawings. The designer, while not considering tolerances, should decide upon the kinds of fit required, which, in turn, makes it possible with the maximum metal dimensions, thus providing for the initial clearance at the time the design is made.

In general, there is a misconception as to the tolerances ordinarily permissible in the building of machines and other mechanisms. It is generally believed that the tolerances on what are considered refined mechanisms are much smaller than they really are; and unless designers thoroughly study the subject, they are inclined to require tolerances that are by no means necessary. It is possible, by the application of expensive machinery operations, to obtain an accuracy of 0.001 of an inch, or even less, but when not essential, such accuracy is highly undesirable from the point of view of economy in manufacture. The rifle is a highly accurate mechanism, and, generally speaking, the tolerances might be considered as small as the tolerances in any other mechanism, yet the average tolerances on the important dimensions of a first-class rifle are about 0.004 of an inch.

The first and most vital principle to be observed in the development of a rational gauging system is to have the locating points in the jigs and fixtures for the machining operations agree with the points used for gauging the work. Unless the gauging is done from the same points as are used for locating the work in the jigs and fixture, it will be found impossible to obtain a product that will be interchangeable.

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